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Assessing the reliability of catch and size statistics estimated using electronic monitoring data collected on Seychelles flagged tuna purse seiners

DANIELLE CHRISTINE JUPITER

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CIHEAM
Instituto Agronómico Mediterráneo de Zaragoza

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Alicante
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Trabajo realizado en la Autoridad Pesqueras de las Seychelles, Puerto de Victoria, Seychelles, bajo la dirección del Sr. Miguel Ángel Herrera de la Organización de Productores de Atún Congelado (OPAGAC) y Dr. Aitor S. Forcada Almarcha de Facultad de Ciencias de la Universidad de Alicante.

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Esta Tesis fue defendida el día 20 de junio de 2017 ante un Tribunal Formado por

- Dr. Bernardo Basurco, Administrador Pesca y Acuicultura IAZM-CIHEAM
- Dr. Alfonso Ramos, Profesor, Universidad de Alicante
- Dr. Pablo Sánchez Jerez, Profesor, Universidad de Alicante
- Dr. Carlos Valle Pérez, Profesor, Universidad de Alicante

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Abstract

Fisheries data forms the basis of fisheries management, simply because without these data it is practically impossible for fisheries managers to know the status of fish stocks, let alone manage them. Having an economy highly dependent on fisheries, Seychelles together with a Spanish organisation of purse seine fishing companies operating in the Indian Ocean, the Producers' Organisation of Large Tuna Freezers (OPAGAC), initiated a process of testing technology-based at-sea monitoring systems to better manage the tropical tuna fishery. The *Satlink* Electronic Monitoring System (EMS) was tested during a seven-month period in 2016 on two Seychelles flagged tuna purse seine vessels. Data collected using EMS was compared to data collected from oversampling of catches in port from selected fish wells. Total retained tuna catch, catch by species and size distribution were compared between the two methods. Results indicated that EMS was more reliable for estimating total retained skipjack tuna (*Katsuwonus pelamis)* and yellowfin tuna (*Thunnus albacares)* as well as for estimating proportions of the total catch by species and proportions of the total catch by commercial size category of bigeye tuna (*Thunnus obesus)*. However, EMS was less reliable for estimating total retained bigeye tuna and assessing fish size distributions. EMS also failed to provide accurate estimates for total retained bycatch. This was due to the set-up of the cameras on the lower deck, that prevented dry observers from obtaining accurate estimates of the number of bycatch retained in each fish tank. Overall, EMS seems capable of producing reliable catch estimates, however, both system configuration and data review protocols require further adjustments in order for EMS to be able to obtain more precise and accurate estimates of catch and size.

Key words: EMS, oversampling, bycatch, total catches, tuna purse seine

Résumé

Les données de pêche constituent la base pour la gestion des pêcheries, tout simplement parce qu'en l'absence de ces données, il est pratiquement impossible pour les gestionnaires des pêches de connaître l'état des stocks de poissons, et encore moins de les gérer. Du fait d'une économie essentiellement dépendante de la pêche, les Seychelles, en collaboration avec une organisation espagnole des entreprises de pêche à la senne coulissante opérant dans l'océan Indien, l'Organisation des Producteurs de Thons Congelés (OPAGAC), ont lancé un processus pour tester des systèmes des technologies de surveillance en mer, afin de mieux gérer la pêche de thons tropicaux. Le *Satlink*, système de surveillance électronique (SSE), a ainsi été testé au cours d'une période de sept mois en 2016 sur deux thoniers senneurs espagnols battant pavillon Seychellois. Les données obtenues par le SSE ont été comparées aux données recueillies lors d'échantillonnages des captures de thons réalisés dans les différentes cuves des senneurs lors du débarquement au Port. Le total des captures de thons, ainsi que les captures par espèce et la distribution par taille ont été comparés entre les deux méthodes. Les résultats indiquent que le SSE est plus fiable pour l'estimation des captures totales de bonite rayée (*Katsuwonus pelamis)* et de thon albacore (*Thunnus albacares)*, ainsi que pour l'estimation des proportions par espèce du total capturé et des proportions par catégorie de taille commerciale du total des captures de thon obèse (*Thunnus obesus)* ; le SSE est moins fiable par contre pour l'estimation des captures totales de thon obèse et celle de la distribution par taille des captures de thons. Le SSE a également échoué à fournir des estimations précises des captures totales de prises accessoires. La mise en place des caméras au niveau du pont inférieur empêchait en effet les observateurs d'estimer de manière satisfaisante le nombre d'espèces accessoires présentes dans chaque cuve. En général, le SSE semble capable de produire des estimations fiables des captures, cependant, la configuration du système et les protocoles d'examen des données nécessitent des ajustements supplémentaires afin que le SSE puisse fournir des estimations plus précises et exactes des captures et distribution par taille de thons et espèces accessoires.

Mots clés : système de surveillance électronique, échantillonnage, prises accessoires, captures totales, thonier senneur à senne coulissante

Resumen

Los datos pesqueros constituyen la base de la gestión de las pesquerías, simplemente porque sin estos datos es prácticamente imposible para los gestores conocer el estado de las poblaciones de los peces y mucho menos gestionarlos de manera adecuada. Con una economía altamente dependiente de la pesca, las Seychelles, junto con una organización española de empresas de la pesca de cerco que operan en el océano Indico, la Organización de Productores de Atún Congelado (OPAGAC), inició un proceso de probar los sistemas de vigilancia en el mar para monitorear la actividad pesquera y mejorar la gestión de la pesquería del atún tropical. El sistema de monitoreo electrónico (SME) de *Satlink* fue probado durante un periodo de siete meses en el año 2016, en dos buques atuneros cerqueros con bandera de las Seychelles. Los datos recopilados mediante el SME fueron comparados con los datos obtenidos mediante sobremuestreo de las capturas de las cubas de pescado seleccionadas en el puerto. La captura total retenida de atún, las capturas por especie y distribución de tallas fueron comparados entre los dos métodos. Los resultados indicaron que el SME era útil en la estimación de la captura de atún listado (*Katsuwonus pelamis)* y atún rabil (*Thunnus albacares)*, además de para estimar la proporción de especies en la captura total y la proporción de categorías de tamaño comercial en la captura del atún patudo (*Thunnus obesus)*. Sin embargo, SME fue menos fiable en la estimación de la captura total retenida del atún patudo y en la distribución de tallas. Además, el sistema tampoco realizó estimaciones precisas de la captura incidental total retenida. Esto fue debido a la instalación de las cámaras en la cubierta inferior, que impidió a los observadores obtener estimaciones precisas de las capturas incidentales retenidas en cada cuba de pescado seleccionadas. En general, el sistema de monitoreo electrónico es capaz de producir datos fiables para la estimación de las capturas, sin embargo, se requieren ajustes adicionales, tanto en la configuración del sistema como en los protocolos de visionado de datos, para que el SME pueda obtener estimaciones más precisas y exactas de las capturas y tallas.

Palabras clave: sistema de monitoreo electrónico, sobremuestro, capturas incidentales, capturas totales, pesquerías de cerco de atún.

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List of Acronyms

ABNJ	Areas Beyond National Jurisdiction
B&A	Bland and Altman Method
BET	Bigeye Tuna
CCC	Concordance Correlation Coefficient
CNCP	Cooperating Non-Contracting Parties
DOS	Digital Observer Services
EEZ	Exclusive Economic Zone
EMS	Electronic Monitoring System
ETA	Estimated Time of Arrival
EU	European Union
FAD	Fish Aggregating Device
FAO	Food and Agriculture Organisation
FL	Fork Length
FPS	Frame per Second
GEF	Global Environmental Fund
GPS	Global Positioning System
HDD	Hard Disk Drive
ICC	Intraclass Correlation Coefficient
ID	Identification
IDP	IsatData Pro
IMO	International Maritime Organisation
IOT	Indian Ocean Tuna
IOTC	Indian Ocean Tuna Commission
IP	Internet or Intranet Protocol
ISSF	International Seafood Sustainability Foundation
IUU	Illegal Unregulated and Unreported
K.S. test	Kolmogorov-Smirnov Test
LD1	Pre-dorsal Length
MCS	Monitoring, Control and Surveillance
MT	Metric Ton
NAF	North Atlantic Format
NVR	Net Video Recording
OPAGAC	Producers' Organisation of Large Tuna Freezers
ppi	Pixels per inch
RFMOs	Regional Fishery Management Organisations
ROS	Regional Observer Scheme
SFA	Seychelles Fishing Authority
SKJ	Skipjack Tuna
SNSOP	Seychelles National Scientific Observer Programme
SVM	Satlink View Manager
t-RFMOs	Tuna Regional Fishery Management Organisations

VMS	Vessel Monitoring System
WIO	Western Indian Ocean
YFT	Yellowfin Tuna

1 Introduction

1.1 Tuna Purse Seining

In the Indian Ocean tuna purse seining began in the early 1980s (Maufroy et al., 2015) whereas, prior to this date, fishing was mainly done with longlines or pole and lines (Ben-Yami, 1994). Furthermore, according to Payet and Lucas (2003) in the Seychelles' Exclusive Economic Zone (EEZ) purse seining activities started in 1983 when the French and Spanish fleets moved from the tropical Atlantic to the Western Indian Ocean (WIO). Purse seining involves surrounding a school of tuna with a net, impounding the fish by pursing the net, and drying up the catch by hauling the net so that the fish are crowded in the bunt and can then be brailed out (Ben-Yami, 1994).

The fishing procedure that is carried out on-board a purse seine vessel to catch tuna, from the shooting of the net, to the end of the hauling with the seine back on board, is called a "set" (Ben-Yami, 1994). There are two main types of set used to capture tuna and they are free schools and schools associated with floating objects (IEO, 2008). A free school set is when a school of fish that has been identified from the surface or detected by vessel's sonar is encircled with a net. An associated school set is when a school of fish that has been aggregated around a floating object is encircled with a net. Floating objects are classified into two categories; natural (for example, a log) and artificial called Fish Aggregating Devices (FADs). FADs are floating objects that have been modified and placed by fishers to attract fish and to facilitate their aggregation and capture. They are usually outfitted with a locator buoy (Ruiz et al., 2014). Furthermore, there exists other types of associations such as with dolphins, whale, whale sharks, sea mounts and anchored FADs. Fishing of tuna schools associated with dolphins only takes place in the eastern Pacific Ocean while the rest occurs in all oceans.

When a school is detected, the size of the school is assessed using vessel's equipment and the skipper determines the direction where the tuna is going before setting the net (Watt, 1986). Then the vessel places itself on the right side of the school and immediately a skiff is released (Ben-Yami, 1994). The skiff is a highly powered annex attached to one extremity of the purse seine which is usually kept on the top of the net at the sloped part of the stern of the vessel. The boat sails around the school of fish at full speed (IEO, 2008). When the school is inside the net, the end of the net is closed and the bottom is pursed. Once the encirclement is finished, the extremity of the net that is attached to the skiff is transferred aboard the vessel. The two extremities of the purse line cable are then hauled with a winch as quickly as possible in order to close the net at its bottom. The net is then pulled aboard the purse seiner with a hydraulic power block. Under the power block, the net is stacked on the stern of the boat by the crew to be ready for the next set. As a whole, this operation can take around one hour or even longer, depending on the size of the net and catch (Ben-Yami, 1994). When most of the purse seine has been retrieved, the fish are harvested from the purse seine using a large scoop net called the "brailer" with a capacity of around 10 MT (IEO, 2008 and Ben-Yami, 1994). Tuna are transported to fish wells/tanks located on the lower deck through conveyor belts and hoppers. The fish are then stored in brine and kept frozen at temperatures of minus 20 °C or lower.

There are three main species of tuna caught in the WIO; yellowfin tuna (*Thunnus albacores) (Table 1)*, bigeye tuna (*Thunnus obesus) (Table 2)* and skipjack tuna (*Katsuwonus pelamis) (Table 3).*

Table 1: The biological characteristics of Indian Ocean skipjack tuna *(Katsuwonus pelamis)* (IOTC, 2016b).

Parameter	**Description**
Range and stock structure	Found in tropical and subtropical waters. Forms large schools, often in association with juveniles of yellowfin and bigeye tuna. Stock assessments consider a single stock for the Indian Ocean as there is no evidence to the contrary. The species is highly mobile and covers large distances.
Longevity	7 years
Maturity	Age: less than two years. Size: 41–43 cm.
Spawning season	High fecundity. Spawns opportunistically throughout the year in the whole inter-equatorial Indian Ocean, north of 20°S, with surface temperature greater than 24°C.
Size (length and weight)	Maximum length: 110 cm FL; Maximum weight: 35.5 kg. The average weight of skipjack tuna caught in the Indian Ocean is around 3.0 kg for purse seine.
Stock status	The skipjack tuna stock is determined to be not overfished and is not subject to overfishing.

Table 2: The biological characteristics of Indian Ocean Yellowfin tuna (*Thunnus albacares)* (IOTC, 2016b).

Parameter	**Description**
Range and stock structure	Distributed mainly in tropical and subtropical oceanic waters, where it forms large schools. They are opportunistic feeders and can dive over 1000 m. Stock assessments consider a single stock for the Indian Ocean as there is no evidence to the contrary.
Longevity	9 years
Maturity	Age: 3–5 years. Size: 100 cm.
Spawning season	Spawning occurs mainly from December to March in the equatorial area (0-10°S), with the main spawning grounds west of 75°E.
Size (length and weight)	Maximum length: 240 cm FL; Maximum weight: 200 kg. Newly recruited fish are primarily caught by FADs. Males are predominant in the catches of larger fish at sizes more than 140 cm. The sizes exploited range from 30 to 180 cm fork length. Juveniles form mixed schools with skipjack tuna and juvenile bigeye tuna and are mainly limited to surface tropical waters, while larger fish are found in surface and sub-surface waters.
Stock status	The yellowfin tuna stock is determined to remain overfished and subject to overfishing.

Table 3: The biological characteristics of Indian Ocean bigeye tuna (*Thunnus obesus*) (IOTC, 2016b).

Parameter	Description
Range and stock structure	Inhabits the tropical and subtropical waters down to around 300m. Juveniles frequently school at the surface underneath floating objects with yellowfin and skipjack tunas. Association with floating objects appears less common as bigeye grow older. Rapid and large scale movements of juvenile bigeye tuna in the Indian Ocean. Stock assessments consider a single stock for the Indian Ocean as there is no evidence to the contrary. The range of the stock includes tropical areas, where reproduction occurs, and temperate waters which are believed to be feeding grounds.
Longevity	15 years
Maturity	Age: 3 years. Size: 100 cm.
Spawning season	Spawning season from December to January and also in June in the eastern Indian Ocean.
Size (length and weight)	Maximum length: 200 cm FL; Maximum weight: 210 kg. Newly recruited fish are primarily caught by FADs. The sizes exploited range from 30 to 180 cm fork length. Smaller fish form mixed schools with skipjack tuna and juvenile yellowfin tuna and are mainly limited to surface tropical waters, while larger fish are found in sub-surface waters.
Stock status	The bigeye tuna stock is determined to be not overfished and is not subject to overfishing

1.2 Monitoring Tuna Fisheries in the Indian Ocean

Fisheries data forms the basis of fisheries management, simply because without these data it is practically impossible for fisheries managers to know the status of fish stocks, let alone manage them (FAO, 1999). Therefore, it is important to collect fisheries related information. In the case of tuna fishery, stocks are managed by respective tuna Regional Fishery Management Organisations (t-RFMOs). According to the European Commission (2016) RFMOs are international organisations formed by countries with fishing interests in an area. For example; the Indian Ocean Tuna Commission (IOTC) is responsible for the management of tuna and tuna-like species in the Indian Ocean. At present, IOTC has 31 Contracting Parties (Members), including Seychelles, and four Cooperating Non-Contracting Parties (CNCP) (IOTC, 2017).

Seychelles is an island archipelago with a massive EZZ of 1.37 million km^2 (Lucas et al., 2014). Port Victoria is the main regional hub for industrial tuna fisheries in the WIO, in particular tuna purse seiners, with nearly 80% of tropical tuna caught in the region transiting annually through its infrastructures (Martín, 2011 cited in Le Manach et al., 2015). Tuna purse seining is carried out by both Seychelles flagged vessels and foreign licensed vessels mainly under flags of European Union (EU) member countries. The tuna fishery is the main foreign exchange earner in the country with majority of the revenues earned from licensing fees. Revenues are also generated from the Indian Ocean Tuna (IOT) cannery as well as from goods and services bought by the companies and crews of the purse seiners in Port Victoria (Le Manach et al, 2015).

The Seychelles Fishing Authority (SFA) is a parastatal organisation which functions as the executive arm of government for fisheries and related matters (SFA, 2014). Its main role is to provide the best science available for the government of Seychelles to take informed management decisions. It collects and records all the fishery related information, including verification and validation of data files, reports compilation and dissemination of information to international organisations such as to the IOTC and the EU (Payet and Lucas, 2003). Basically, there are two categories of data required for tuna purse seiners in Seychelles; data collected by the fishing sector (logbook, well-map and unloading data) and data collected by SFA staff as part of their regular duties (regular sampling in port and scientific observer programme). Regular sampling data are used in combination with logbooks, well's map and unloading data to produce final estimates of retained catches by species and length for the purse seine fleet.

The scientific observer programme is the deployment of scientific observers' on-board tuna purse seiners for the collection of at-sea fishery information. The programme was created following adoption of Resolution 11/04 by the IOTC, which calls for the implementation of a Regional Observer Scheme (IOTC ROS) aiming to improve the amount of information available on bycatch, the non-target species caught, and discards as well as validate other information reported by the fishing sector (IOTC, 2011). This is necessary because the extent to which vessel operators misreport bycatch and discards is unknown. Therefore, the information gathered by observers can be used to verify and complete logbook information. Furthermore, observer data provides information that makes it possible to manage what is caught, not just what is landed and reported. This is important because the difference (bycatch and unreported catch) affects the assumptions about the mortality of species or age classes (National Academy of Sciences, 2000). This resolution calls for IOTC Members and CNCP to deploy observers on their industrial fishing vessels to cover at least 5% of the fishing operations (IOTC, 2011).

Following adoption of the IOTC ROS, Seychelles initiated a process to ensure that vessels under its flag complied with the new requirement. In July 2013, SFA began the deployment of scientific observers on industrial tuna purse seiners under the framework of the Seychelles National Scientific Observer Programme (SNSOP) (Lucas et al., 2014). In 2015, a 100% observer coverage was met after the implementation of a Code of Good Practices agreed by the main tuna purse seine operators in the Indian Ocean. Yet, despite tremendous effort for the execution of the scientific observer programme, there are several shortcomings that limit its use. As reported by Ruiz et al. (2015) the complexity of the fishing operation of purse seiners makes it difficult for one observer to monitor all fishing activities, as this would require simultaneous monitoring of both upper and lower decks for each successful fishing set. Often the lack of space on-board tuna purse seiners makes it impossible to cater for more than one observer. The use of human observers is also compromised in the context of the purse seine fishery because it operates on the high seas and holds access agreements to EEZs of various coastal states in the WIO. These agreements may require the boarding of observers from these coastal states when purse seiners enter their respective EEZs. This hampers their operation because they already have an initial observer on-board. Therefore, this makes it difficult for purse seiners to enter more than one EEZs during a single fishing trip. While several initiatives to create "pools" of regional observers have been implemented, some coastal states do not accept observers from other parties when purse seiners enter their EEZs and require that their own observers board those purse seiners. These challenges make it difficult to ensure that level of coverage on most fishing vessels is adequate and consequently may reduce the usefulness of data obtained for management purposes.

1.3 Electronic Monitoring Systems for Tuna Fisheries

Technology-based sea monitoring is used to complement human observers' on-board tuna purse seiners (Ruiz et al., 2016). Electronic Monitoring Systems (EMS) was developed to monitor fishing activities, with a view to improve scientific data collected and to facilitate regional arrangements for Monitoring, Control and Surveillance (MCS) (*Table 4*). The system is based on the recording of geo-referenced video footages from several cameras installed on vessels, intended to cover all fishing activities, such as loading, unloading as well as other associated operations (McElderry, 2008). Several studies have been carried out in the past to test the performance of EMS in monitoring fishing operations in tuna purse seine trips. The first pilot study was conducted in 2012 by the International Seafood Sustainability Foundation (ISSF), with the system installed on three vessels, one per ocean, these were: the Spanish owned vessel *Playa de Bakio* in the Atlantic Ocean; the French owned vessel *Torre Guilia* in the Indian Ocean and the US owned vessel *Cape Finisterre* in the Pacific Ocean. The system used for the pilot was manufactured by Archipelago Marine Research Limited in Victoria, Canada (Ruiz, 2015). The outcomes of the study demonstrated that this kind of technology has great potential for the monitoring of purse seine trips. Since then, there have been new systems developed by numerous commercial vendors. One of the newer systems is the *Electronic Eye* developed by *Marine Instruments*. *Electronic Eye* was tested in 2014 on a tropical tuna purse seine vessel operating in the Atlantic Ocean (Ruiz et al, 2014). Another recently designed system is *SeaTube* manufactured by *Satlink*. According to Monteagudo et al. (2014) this system had been installed on at least 17 EU flagged and associated purse seine vessels worldwide. Furthermore, it is being used in Fiji, Ghana and the Cook Islands, thanks to the support of various initiatives such as the Areas Beyond National Jurisdiction (ABNJ) Tuna Project and the Producers' Organisation of Large Tuna Freezers (OPAGAC) (M. Herrera, personal communication, 11th May, 2017).

Table 4:Comparing human observer to EMS in relation to science and compliance on-board tuna purse seiners.

Task	Science	Compliance	Human Observer	EMS
Vessel Data & Equipment	Yes	Yes	Obtained information from vessel's crew.	Equipped with independent GPS which allows the monitoring of vessel position, route and speed at a much finer scale than a human observer (Ruiz et al, 2016).
Information on Gear	Yes (e.g. # FAD deployed)	Yes (e.g. Seine depth)	Make their own observations as well as obtained information from vessel's crew.	According to Ruiz et al (2016) accuracy between 72 and 100% for set type. Different data sources are used: visual evidences (detecting a FAD in a picture/video), species composition (detection of species characteristic for a determined type of set), or vessel behaviour (GPS and sensor information).
Effort Data	Yes	Yes (e.g. Area Closures, FAD limits)	Obtained information from vessel's crew.	100% accuracy in identifying the number of fishing sets as well as dates, hours and positions (Ruiz et al, 2016).
Retained Catch Data Target Species	Yes	Yes (e.g. TAC)	Obtained information from vessel's crew.	Equipped with cameras both on the upper and lower deck. Dry observers estimate tuna catch from video footages.
Retained Catch Data Bycatch Species	Yes	Yes (e.g. retention ban)	Sampling is carried out.	Equipped with cameras both on the upper and lower deck. Dry observers sample bycatch from video footages.
Discards Data	Yes	Yes (e.g. full retention policy)	Make their own observations.	Equipped with cameras both on the upper and lower deck. Dry observers estimate discards from video footages.
Size Data (Retained Catch & Discards)	Yes	Yes (e.g. size limits)	Obtained information on retained tuna from vessel's logbook and well-map. Sampling of retained bycatch, discarded tuna and discarded bycatch.	Software for review and analysis of EMS data have measurement scale which permits the dry observers to estimate size of fish.
Biological Sampling	Yes (e.g. sex & maturity, otoliths)	No	Able to performed the task.	Unable to performed the task.
Interactions	Yes	Yes (e.g. bans fishing tuna schools associated with marine mammals, whale sharks, etc.)	Able to performed the task, however, can be influenced or intimidated by crew.	Cameras on vessels permits to monitor fishing activities.
Sightings IUU other vessels	No	Yes (e.g. illegal transshipment; fishing prohibited gears/areas)	One observer cannot monitor all IUU of vessels due to tiredness, poor weather, and illness, therefore, rely on skippers to provide data.	Cameras on vessels permits to monitor IUU of vessels.
Data on crew	No	Yes (e.g. #crew, origin, etc.)	Can be influenced or intimidated by crew.	Cameras on vessels permits to monitor the activities of the crew.
Overall Data Validation	Yes	Yes	No opportunity to quality assure the data gathered at sea.	The data is available for subsequent quality assurance reviews. EMS is more reliable because there is no possible corruption as images can be verified as many times as needed.

Despite past efforts to test the reliability of EMS, in all previously mentioned studies the main focus had been on comparing data collected using EMS against data collected by scientific observers during the same fishing trips. For instance, the Marine Resources Assessment Group's (MRAG) comprehensive audit of the *SeaTube* system indicated that there was no significant difference in vessels activities and catch estimates between at-sea human observers and electronic observer data analysed in land, at the end of each fishing trip (MRAG, 2016). While those studies are encouraging, data collected at sea by both electronic observers and human observers, in particular catch estimates, are likely to be subjected to various sources of bias. In general, human observers raise estimates using both their own observations (e.g. bycatch and discards) and estimates made by others (e.g. retained tunas as estimated by the vessel crew) (Ruiz, 2013). There is no precise benchmark from which the accuracy of catch estimates derived from EMS data can be measured. Hence, to test the true capabilities of EMS, estimates obtained from EMS data should be compared with data obtained from direct measurements. In this study, catch estimates from EMS were compared to data collected from oversampling of catches within selected fish wells, intended to measure as many fish as possible throughout the unloading event of each tank. In addition, data from EMS was also compared to catch estimates obtained from other sources: well-map, logbook, regular sampling, unloading, and scientific observer data.

This pilot activity was carried out by SFA and OPAGAC and received financial support from OPAGAC and the Common Oceans ABNJ Tuna Project, managed by the Food and Agriculture Organisation of the United Nations (FAO), funded by the Global Environmental Facility (GEF). According to FAO (2015) the goal of this pilot activity, was to strengthen the capacity of SFA to monitor Seychelles flagged vessels and prove that EMS can be used in the Indian Ocean to monitor the activities of domestic and foreign licensed vessels, in a transparent, efficient, and cost-effective way and to complement human observers. This activity was in line with Component 2 of the ABNJ Project - Strengthening and Harmonizing MCS to Address Illegal Unregulated and Unreported Fishing (IUU)- in particular Outcome 2.1. MCS systems, particularly those addressing IUU fishing and related activities are strengthened and harmonized over all five t-RFMOs, as well as with Output 1.1.2 of the project: Increased capacity of ten coastal developing states to comply with t-RFMO member states obligations, through enhanced compliance with IOTC Resolution 11/04.

Hence, obtaining retained and discarded catch data of purse seine set from EMS would highly improve the resolution of the estimates for this fleet as catches by set cannot be precisely estimated using the existing sampling and estimation procedures. This would also extend the capabilities of EMS beyond those it currently has, particularly in the monitoring of vessel activities, including discards at sea.

1.4 Objectives

The main objective of this study was to test the ability of EMS to produce reasonably precise and accurate estimates of retained tuna catch and retained bycatch, on trips from two Seychelles flagged tuna purse seine vessels conducted over a period of seven months.

The specific objective of this study was:

- Compare the data collected using EMS to the data collected from oversampling of catches in port from selected fish wells, to determine if EMS records can be used to obtain reliable catch estimates on commercial purse seine vessels. The study was divided into two specific tasks:
    a. Evaluate the reliability of EMS to estimate total tuna catch, catch by species and/or size by fish tank.
    b. Evaluate the reliability of EMS to estimate total bycatch by fish tank.

Further objectives of this study were:

- Compare the data collected using EMS to the data collected by scientific observers to evaluate the reliability of EMS to estimate total discarded tuna catch and discarded tuna catch by species by trip.
- Compare the data collected using EMS to the data collected by scientific observers to evaluate the reliability of EMS to estimate total bycatch, total retained bycatch and total discarded bycatch by trip.
- Compare the data collected using EMS to the data collected from unloading to evaluate the reliability of EMS to estimate total retained tuna catch, retained tuna catch by species and/or size by trip.
- Compare the data collected from regular sampling to the data collected from oversampling from the selected fish wells to evaluate the reliability of the regular sampling protocol to estimate tuna species composition and size class by fish tank.
- Compare the fish storage data recorded on well-map to the data collected from oversampling to evaluate the reliability of crew estimates for total tuna catch, catch by species and/or size by fish tank.
- Compare the fish storage data recorded on well-map to the data collected from unloading to evaluate the reliability of crew estimates for total tuna catch, catch by species and/or size by trip.
- Compare the data recorded on logbook to the data collected from unloading to evaluate the reliability of crew estimates for total tuna catch, catch by species and/or size by trip.

2 Methodology

2.1 Study Site

SFA was responsible for the implementation of this pilot study, which took place in the western tropical and sub-tropical Indian ocean. SFA is located in port Victoria, Seychelles, between 3 and 10 degrees south of the equator and between longitude 46 and 57 degrees east in the WIO (*Figure 1*). Port Victoria was an ideal location for this study because Seychelles has one of the largest EEZ in the region and hosts the main tuna hub in the WIO (Martín, 2011).

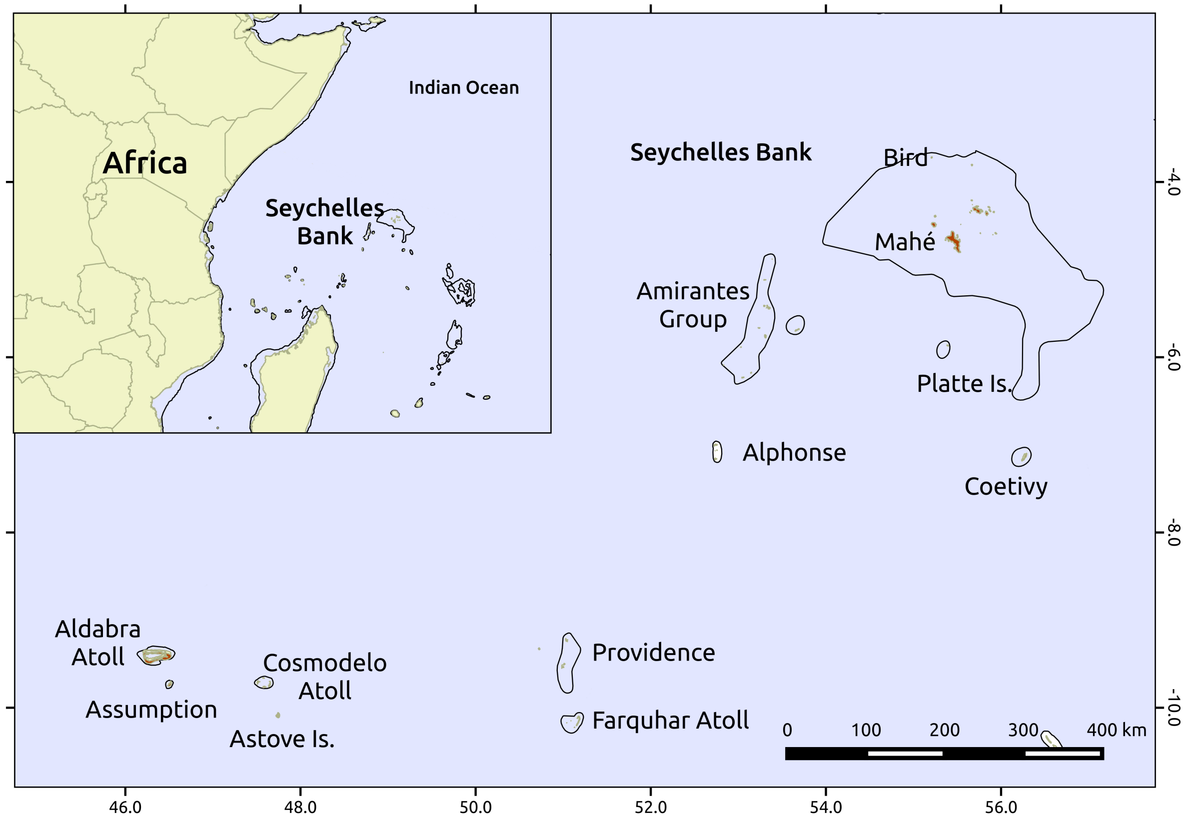


Figure 1: Map showing location of the Seychelles archipelago.

2.2 Data Collection

Fisheries data was collected by EMS on two Seychelles flagged tuna purse seiners namely *Intertuna Tres* and *Galerna III* from May to December 2016. At the end of each fishing trip, Hard Disk Drives (HDD) were retrieved from vessel by *Satlink* technician for review and analysis of EMS data by dry observers in land. Samplings of fish from selected fish wells were carried out on the two vessels in port. There were two different types of samplings that were carried out on the same selected fish wells: oversampling (the main sampling activity of this study) and regular sampling. A total of eight fish tanks, one per each trip were oversampled and seven out of eight fish tanks were sampled by the regular sampling protocol. Length measurements obtained from oversampling and regular sampling were converted to weight, in order to performed comparative analyses with other datasets collected during this study: the scientific observer programme, logbooks, well-maps and unloading. A number of variables such as total retained tuna catch and retained tuna catch by species were measured from sampling methods.

2.2.1 Vessel Details

The *Satlink* electronic equipment was installed on two Seychelles flagged tuna purse seiners belonging to the *Albacora* group, namely *Intertuna Tres* (*Figure 2* & *Table 5*) and *Galerna III* (*Figure 3* & *Table 6*). Installation of the system on *Intertuna Tres* was completed and commissioned on the 16th May 2016 while on *Galerna III* the same exercise was completed one month later on the l6th June 2016. Catch data from 333 fishing sets was collected by EMS over a period of seven months. Detailed information on the ten fishing trips conducted by the two vessels is provided in *Table 7* and *Figure 4* shows the location where fishing of the 21sets of which catches were stored in the eight oversampled fish tanks.

Figure 2: *Intertuna Tres* in Port Victoria Seychelles.

Table 5: Details of vessel *Intertuna Tres*.

Identification	Dimensions
Flag: Seychelles	Overall Length: 101.66m
Year Built: 1999	Number of Holds: 26
IMO: 9202704	Gross Tonnage: 4428
	Fish Carrying Capacity: 3264m^3

Figure 3: *Galerna III* in Port Victoria Seychelles.

Table 6: Details of vessel *Galerna III*.

Identification	Dimensions
Flag: Seychelles	Overall Length: 84.85
Year Built: 2014	Number of Holds: 22
IMO: 9663166	Gross Tonnage: 3455
	Fish Carrying Capacity: 2343.9m3

Table 7: Dates and Number (N^o) of fishing operations during five sampled trips per each purse seiner.

Vessel	Trip	Departure	Return	N^o of Sets	Total Sets
Intertuna Tres	1	25.05.2016	02.07.2016	35	195
	2	05.07. 2016	05.08.2016	41	
	3	09.08.2016	04.10.2016	51	
	4	08.10.2016	05.11.2016	39	
	5	07.11.2016	10.12.2016	29	
Galerna III	1	16.06.2016	13.07.2016	29	138
	2	20.07.2016	18.08.2016	34	
	3	21.08. 2016	22.09.2016	26	
	4	24.09.2016	17.10.2016	24	
	5	20.10. 2016	11.11.2016	25	

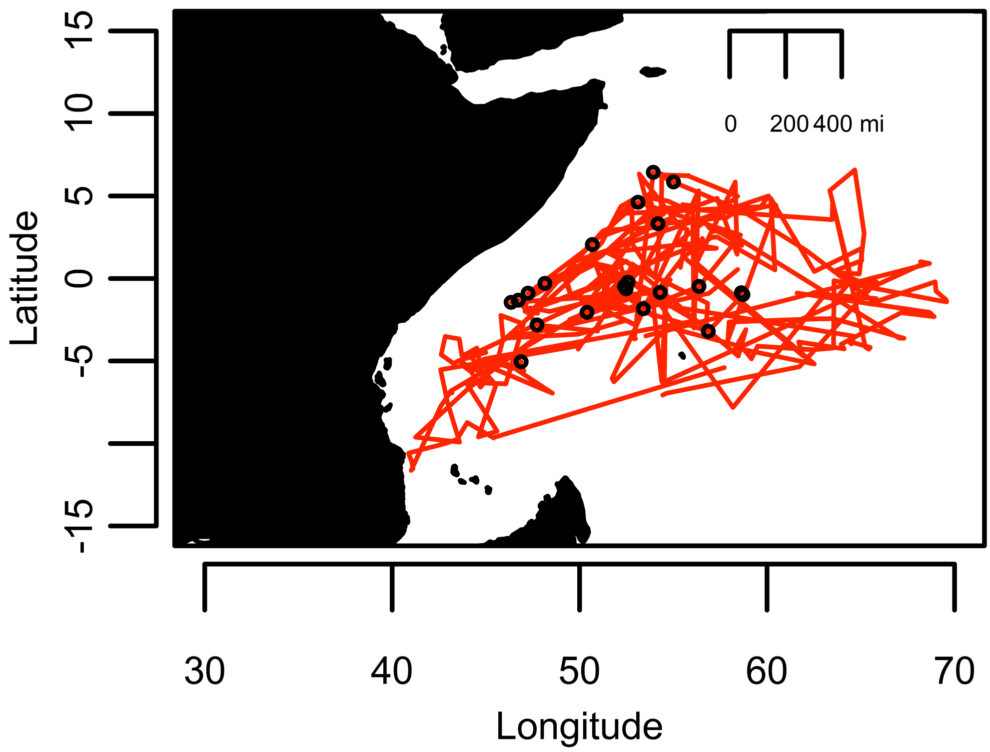


Figure 4:The area explored and fished over the seven months' period of the study. The black circles represent the 21 sets for which catches were stored in oversampled fish tanks.

2.2.2 Electronic Monitoring System

The EMS used for this project was *SeaTube* manufactured by *Satlink* in Spain. The *SeaTube* system consists of several components (*Figure 5*):

- Equipment on-board: Main unit (*Figure 6)*, VMS unit (GPS antenna) and IP cameras.
- Equipment on-shore: *Satlink* Secure Server, Alarm System and Daily Report System.
- Video review and data analysis: *Satlink* View Manager (SVM) software, two screens and office (dry) observers.

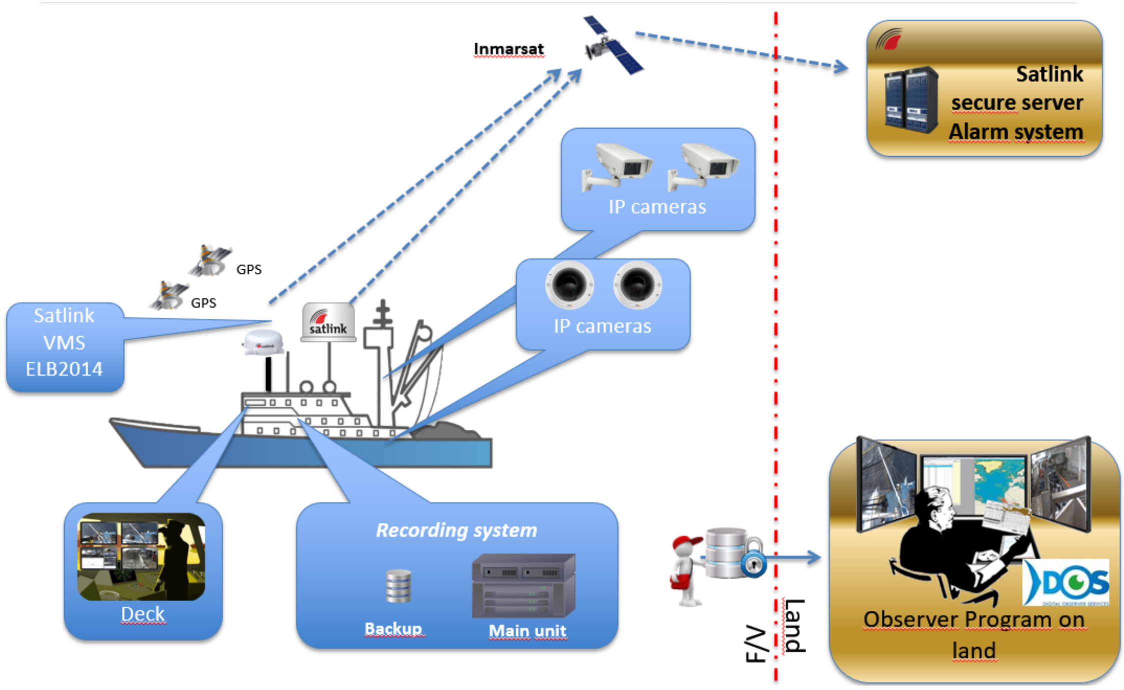


Figure 5: The several components which make up the *SeaTube* Electronic Monitoring System (Legorburu, 2016).

Figure 6: The main unit contains the interconnection box, management server, net video recording (NVR) unit and backup unit (Legorburu, 2016).

VMS Unit: The tamperproof Vessel Monitoring System unit (ELB2014) is an electronic communication device, which uses its GPS system to gather GPS (latitude, longitude, speed, course, date and time) and EEZ area information. Such information is continuously stored in the main unit every minute or every configurable period up to 10 seconds. Every hour a full position report is sent over-the-air through the VMS unit via Inmarsat satellite system to the *Satlink* secure server located on land. The VMS unit is also responsible for sending alarms to the alarm system in Spain as well as randomly generated passwords and daily reports, including information on the generated videos and free space available in the main unit (Legorburu, 2016).

Management Server: The Dell all-in-one server is the "brain" of the system and is located inside the main unit. Its responsibility is storing the configuration of the recording option; which is to record 24 hours 7 days a week. In addition, any remote-control instruction must be given to this server and any vessel information such as state flag and vessel identification number can be introduced here. The management server is also the unit which generates alarms, daily reports (HDD memory consume) and disks passwords. It monitors alarms and notifies the VMS unit to send them through the satellite system and once an alarm is recovered the server informs the VMS unit to send another recovery alarm; closing it. In addition, this server has the ability to tell the VMS unit to send daily reports with the generated videos in the last 24 hours and the free space on the system. Disks passwords are also sent using the VMS unit, being the server responsible for managing the creation and encryption of the data. Each video stored in the system has metadata information on it. This information has the full GPS string (in a North Atlantic Format (NAF) and vessel data. It allows the identification of any video to a vessel, a position and time. The management server unit is responsible for maintaining that metadata stored in each video. Each video has a watermark on the top left corner with the vessel name, position, date and time. This watermark is updated from the server in each stream of each camera and cannot be modified by anyone (Legorburu, 2016).

IP cameras: The *SeaTube* system includes a scalable number, usually up to eight, cameras. In this study, a total of seven cameras, four on the upper deck and three on the conveyor belt at the lower deck, were installed on each sampling vessels, *Intertuna Tres* (*Figure 7*) and *Galerna III* (*Figure 8*) (Legorburu, 2016). The cameras used are AXIS P3364-VE or similar model with the following characteristics:

- Video frame rate: 24fps.
- Angle of vision: 105º
- Codec: H264 (mp4)
- Video Resolution: 1280x720 ppi
- Video fragmented into 10 minutes' video

Optionally, each video can be downgraded to extract still images every configurable period of time (Legorburu, 2016).

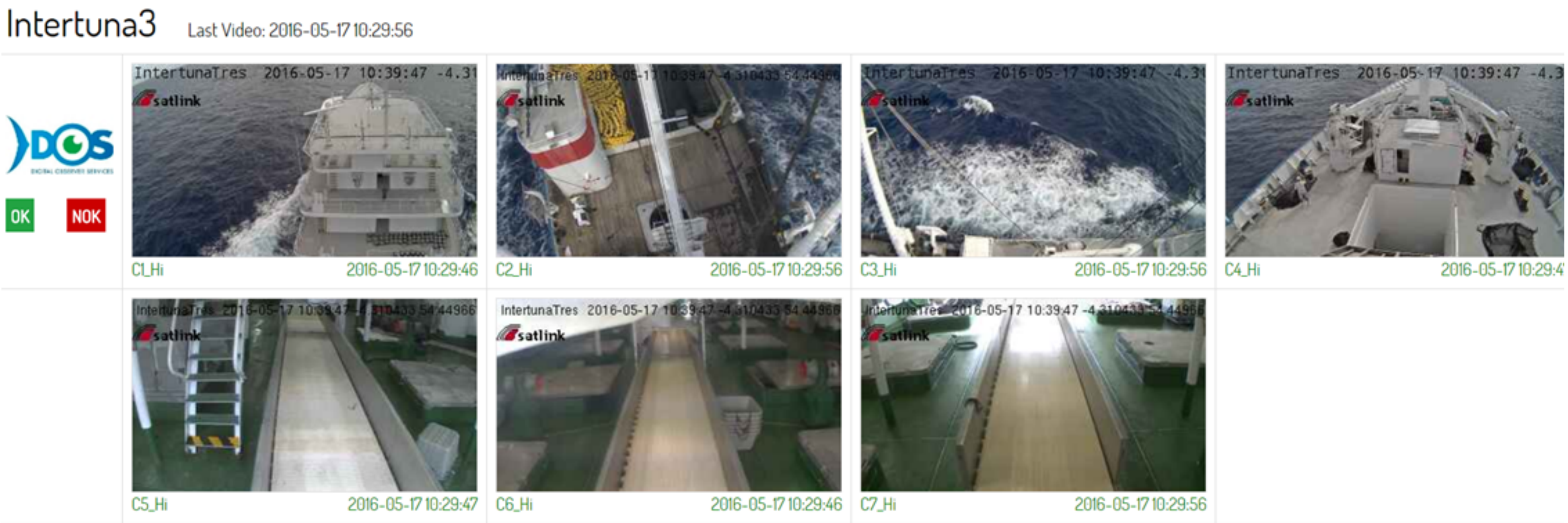


Figure 7: The specific location of the seven cameras (C1 to C7) configuration on vessel *Intertuna Tres*. C1 and C3 covers mostly all the net when settled. C1 shows approaches to FADs or any other observed system (birds, free schools, other vessels etc.) C2 shows the final purse area, brailing and bycatch handling on deck. C3 shows portside crane manoeuvres. C4 shows bow cranes. C5 shows fish drop into wells from 11 to 13 (both sides) and fish going forward. C6 shows fish drop into wells from 8 to 4 (both sides) and fish going forward. C7 shows fish drop into well 3 to 1 (both sides) and possible discards from bow side (Legorburu, 2016).

Figure 8: The specific location of the seven cameras (C1 to C7) configuration on vessel *Galerna III*. C1 is 360 degrees but has been configured to view only at 180 degrees to cover all the port side and most of the net when settled. C2 shows brailing and bycatch handling on deck. C3 shows speedboats' deck cranes. C4 shows bow cranes. C5 shows fish drop into wells 11 to 10 (both sides) and fish going forward. C6 shows fish drop into wells 9 to 5 (both sides) and fish going forward. C7 shows fish drop into wells 4 to 1 (both sides) and possible discards from bow side (Legorburu, 2016).

NVR Unit: The unit (Synology) is the primary recording device in which videos are stored first for redundancy reasons (Legorburu, 2016).

Backup Unit: The unit (Synology, removable disks unit) is where the videos will be extracted. Disks inserted in this unit are extractable, and the disks are stored in four bays. Each disk is encrypted with a long password generated every time a new disk is inserted in this unit (Legorburu, 2016).

Satlink Secure Server: The server is located on land and it is where the GPS positions are stored. It has the ability to trigger the alarm system if the last VMS transmission is older than one hour (Legorburu, 2016).

Alarm System & Daily report system: Active health checking system is a program installed in the main unit to detect anomaly behaviour. Whenever an anomaly behaviour is detected the management server is immediately notified and the server informs the VMS unit to report with an alarm to the alarm system. Every 24 hours a message is sent through the VMS unit via satellite sending the number of videos recorded and it size, space available for each disk and total amount of space. The alarms that are able to be detected and send through the satellite system:

- Unreachable camera
- Unreachable IDP
- Unreachable NVR
- Unreachable backup unit
- Camera not recording
- GPS too old
- Metadata not updated in video footages
- High number of videos not copied to backup
- Shutdown detected on the system
- Disks problems
- Low space on disks
- User logged in to server (Legorburu, 2016).

Review of EMS data

Digital Observer Services (DOS) is an electronic monitoring service provider specialized in the *Satlink SeaTube* EMS. EMS trip data was reviewed and analysed by three DOS certified SFA's dry observers in Victoria, Seychelles. The dataset was referred to as SFA EMS. EMS data were also reviewed and analysed by dry observers from DOS in Bilbao, Spain, in order to validate the work produced by the SFA team. However, DOS only reviewed the stream of video footages which corresponds to the oversampled fish wells. DOS reviewed and analysed the EMS data twice and the two datasets were referred to as DOS EMS sampling one (S1) and DOS EMS sampling two (S2). The software used to review and analyse the data was the SVM developed by *Satlink* itself. The software enables the dry observers to navigate through the entire set of recorded data by applying various filter options such as vessel speed and elapsed time to filter fishing events from the rest of the recording. According to Monteagudo et al (2014) a speed of 2.5 knots or below, for at least 60 minutes, indicates that a set is taking place. Once the data has been filtered and all the sets have been identified, the dry observers have to determine the positions, dates and times of the start and end of each set, the set type, the level of fullness in percentage (translated into weight in tons of each brailer), the species composition (percentage and weight category of each target species), whether there has been any discard on target species and the estimated amount and size category of tuna species. In addition, bycatch is recorded, in terms of the number of individuals, their FAO species code, as well as approximate size and fate (Monteagudo et al, 2014). The protocol followed by the SFA's dry observer can be found in *Appendix 1*.

2.2.3 Oversampling

In this study oversampling consisted on the total enumeration of fish unloaded from selected fish wells, in number, and the collection of large samples of fish taken at different times during the unloading operation. Therefore, the sampling unit was the fish well, in which fish from one or more sets have been stored. The purpose of conducting the oversampling was to obtain an accurate estimate of the total catch by species and size class in the fish wells. SFA was the responsible body for the implementation of this activity. Six personnel comprising of a team leader and five enumerators took part in the oversampling activity. A total of eight fish wells, one per each fishing trip were oversampled. The oversampling protocol provided by Miguel Herrera from OPAGAC can be found in *Appendix 2*; however, the protocol was slightly changed to fit with the actual situation faced by the samplers during the oversampling activity.

Selection of fish wells
The captain informed the team leader via email of their Estimated Time of Arrival (ETA) and sent a copy of the well-map prior to their arrival in Port Victoria in order to facilitate logistical arrangements, for instance; informs the enumerators prior to the date and time of the oversampling activity especially if the vessel arrival was expected on a weekend. The team leader used the copy of the well-map to select the well to be sampled and informs the captain about it so that, where possible, the fish tank will not be open until the arrival of the sampling team.

The protocol clearly states that where possible, the well selected shall not contain fish from a set from which the catch has also been stored in other fish well(s), in particular if loading of the fish wells has occurred simultaneously (i.e. two or more fish wells open at the same time while loading the fish from the set). This is necessary for the identification of the stream of video footages from EMS that relates to the fish in the well selected for oversampling so that the analysis refer to the same fish.

The chief engineers on the two vessels assured the team leader that loading of fish in fish wells did not occur simultaneously, but rather they were opened one at a time. Furthermore, they tried to follow a pattern by starting with wells amid ship and continued towards the stern. Only when the biggest stern wells were already full, they proceeded towards the bow. However, due to the actual size of the wells on the two vessels (for example, on *Intertuna Tres* the well's capacity are from 65 to 115 tons), it was very rare to find one well containing only one set or that full sets had completely filled up a specific fish well. This was because at the time of the year the project was conducted, the FAD sets were not big enough to fill up a particular well. In order to follow protocol, the team leader avoided fish wells containing mixed sets or fish from the same set stored into different wells. Later on, however, the team leader could no longer avoid these wells due to the difficulties encountered during oversampling. For instance, the team leader could not choose the most appropriate wells on a few occasions as that would disrupt the unloading procedure. Some of the situations encountered were wells already opened and stevedores unloading fish prior to the arrival of the sampling team, fish from the selected well could not be unloaded because they had not reached the right temperature, fish over 10 kg have not yet been sold or were going to be transferred to other wells to be discharged on a different day and the lack of brine to be able to operate in a new well without delaying the vessel's commercial operation.

According to the protocol a total of ten fish wells should be sampled and the first oversampling carried out on each vessel should be a trial. In addition, the fish wells selected should contain different typologies of fish (in terms of species and size) so that at the end of the project samples from as many typologies as possible can be compared. The objective was that at the end of the project:

There are at least two samples available from the following typologies (these two refer in general to free-school sets):

- Fish wells that contain only large fish
- Fish wells that contain only small fish or where it represents the large majority of the catch (only some specimen of large fish reported on well-map, or none)

There are at least four samples available from fish wells that contained a mix of fish from various sizes (these generally refer to associated-school sets or a mix of free and associated-school). The team leader shall try to select fish wells with various degrees of mix regarding set, school type, size and species.

Since the first oversampling conducted on each vessel was as good as the rest of the oversamplings performed during the project, data collected from all the samplings were used in the analysis. However, only eight of a scheduled ten oversamples were undertaken. This was because the first oversampling activity scheduled for vessel *Intertuna Tres*, from the 2nd to the 4th July 2016, could not be undertaken due to logistical constraints and cancellation of the last oversampling organized on the 10th December 2016 because fish caught on that trip were of the same typology as those previous sampled. The team had sampled fish wells containing mixed typology, mostly dominated by small specimens, with the majority sampled from associated-school sets except for one which was sampled from a mix of free and associated-school sets. On all of the ten fishing trips, there were no fish wells containing only free-school sets. This was because the fishing trips took place from May to December 2016 and in this period, it was not possible to obtain a single well containing free-school sets of any fish category, big or small.

Sampling procedure

The objective was to count all fish in the selected well (disregarding species) and take a sample as large as possible, in order to breakdown the catches within the well according to species and size.

It is impossible for samplers to count all the fish being unloaded eyeball. This is because unloading of fish is done very fast. Therefore, a camcorder was used to record all fish throughout the unloading event of the well. Then after oversampling, the recorded data was reviewed and all fish unloaded from those images were counted. Tuna were classified into two categories: fish having fork length greater than 80 cm and fish having fork length smaller than 80 cm. According to Fonteneau et al. (2010) this is because the EU sampling is stratified by size which corresponds to categories of more and less than 10 kg. Also, when unloading the boats, the stevedores usually separated fish into those categories, because each category fetches a different price and sometimes goes to different markets (M. Herrera, personal communication, December 7, 2016).

For the intensive sampling of fish throughout unloading of the selected well, the team leader adjusted the protocol in order to have a more representative sample of fish from the selected fish wells. In all of the eight oversampled wells, the enumerators took five subsamples of a minimum of 200 tuna fish (disregarding size category) from each fish well throughout the entire unloading, totalling over a 1000 fish. The team leader had to consider the fish typology and fish quantity in the tank as well as the pace of unloading in order to decide when to carry out the five subsamplings. In every oversampling, the duration of unloading was different, varying from four to ten hours. The first subsampling was done shortly after the opening of the fish well while the last subsampling was taken prior to the removal of brine from the fish well. Brine was removed from fish well because there were few fish left as they were no longer floating on the surface, they were rather stuck at the bottom or in between the pipes inside the well. Furthermore, when all five samplers were present, or when fish were unloaded without the use of a hopper (meaning the unloading was slow) the samplers were able to measure all the large fish from the fish well. However, when the hopper was used or when there were fewer samplers present, it was impossible for the samplers to measure all the large fish. Therefore, only during some of the oversampling occasions were all large fish measured and counted, while on the rest, the large fish were sampled in the group of 1000 fish covered by the oversampling protocol. As for non-tuna species, i.e. the bycatch, enumerators measured all specimens unloaded from the well.

2.2.4 Regular Sampling

This is the sampling of fish from selected fish wells by enumerators in port. Samples are selected depending on the type of fish in the selected well: if all fish is of large size (length equal or greater than 80 cm) the enumerators take two samples of 100 fish each, at different times during the unloading, classify by species and measure all fish by length. If there is small fish in the well (mixed or not with large fish) the enumerators will do as follows:

- Fish having length 80 cm or greater: Enumerators sample for length and species as many fish as possible from the well;
- Fish having length smaller than 80 cm: Enumerators take two samples, at different times during the unloading, sampling 300 fish and then 200 fish (500 fish in total). Each sample consist on measuring for length (first 50 skipjack tuna and all other species) and counting (remaining skipjack tuna) from the selected well.
- The measurements taken are Fork Length (FL) for individuals smaller than 80 cm and Predorsal Length (LD1) for larger individuals

In this study a total of seven regular samplings were carried out during the same period of the oversampling activity and on the same fish wells.

2.2.5 Other Data Sources

Scientific Observer Programme Data: Information on the activities of purse seiners at sea collected by scientific observers. These include: retained tuna catch by trip, fish tank, species and commercial size category as well as discarded tuna catch by trip and species. Furthermore, retained and discarded bycatch by trip.

Logbook Data: Logbooks are used to record the activities of purse seiners while at sea. They mainly contain retained tuna catch information. Retained tuna catch data is recorded per each successful fishing set and categorised by species and commercial size category. Logbooks are completed by the captain or the fishing master.

Well-map Data: Purse seiners store their catches in fish wells, located in the lower deck. Thus, the catches from each set are stored in one or more fish wells. This depends on the size of the well and the catches made on that set. Chief Engineers keep a record of the amount of tuna stored in each well, by set, species and commercial size category.

Unloading data: Data collected in port at the end of each trip. Tuna catch data are categories by species and commercial size category.

Details on the compilation of data from other sources can be found in *Appendix 2*.

2.3 Data Processing and Variables measured

Length measurements obtained from oversampling and regular sampling were converted to weight in order to perform comparative analyses with other datasets such as scientific observer programme, logbook, well-map and unloading. This was done using the available length-weight relationship equations. There were two types of lengths that were measured, using callipers, during the sampling activity and they were fork length (FL) and pre-dorsal length (LD1). Fork length were taken in all oversamplings for all the species (note that only the group of 1000 fish covered by the oversampling protocol was used in the analyses) and in the regular sampling it was taken only for small specimens. Fork length is measured from the tip of the snout to the fork of the tail. Pre-dorsal length was taken only in the regular sampling for large individuals of yellowfin and bigeye tuna. Pre-dorsal length is measured from the tip of the snout to the base of the first dorsal fin.

The conversion from pre-dorsal length to fork length used two different methods, LD1-FL key (Chassot et al., 2014) and the deterministic procedure $FL=a\cdot LD1^{b}$ (E. Chassot, personal communication, February 4, 2017). Parameters; intercept (a) and slope (b) used in the equation for yellowfin and bigeye tuna were obtained from EU scientists. Furthermore, since pre-dorsal length was measured to the lowest half cm; it was necessary to add 0.25 cm to each length measurement in the equation. The conversion from fork length (FL) to weight (W) used the equation, $W= a\cdot(FL)^{b}$. Two different types of parameters; intercept (a) and slope (b) were used in the equation for each tuna species, parameters obtained from the EU scientist (E. Chassot, personal communication, February 4, 2017) as well as parameters used by IOTC (IOTC, 2016a) (*Table 8*). Moreover, because fork length was measured to the lowest cm, it was necessary to add 0.5 cm to each length measurement in the equation.

Table 8: Parameters; intercept (a) and slope (b) used by European Union scientists for the conversion from pre-dorsal length (LD1) to fork length (FL) for yellowfin (YFT) and bigeye (BET) tuna, from fork length (FL) to weight (W) for yellowfin (YFT), bigeye (BET) and skipjack (SKJ) tuna and parameters used by IOTC for the conversion from fork length (FL) to weight (W) for yellowfin (YFT), bigeye (BET) and skipjack (SKJ) tuna.

EU Parameters for LD1 - FL	YFT	a	1.777978	BET	a	1.848427				
		b	1.173612		b	1.180895				
EU Parameters for FL - W	YFT	a	0.000017665	BET	a	0.000030519	SKJ	a	0.000011146
		b	3.03542		b	2.94297		b	3.19207
IOTC Parameters for FL - W	YFT	a	0.00001886	BET	a	0.000027	SKJ	a	0.00000748
		b	3.0195		b	2.951		b	3.2526

Furthermore, samples taken in length and weight were raised to obtain total number of fish per fish tank, species, size class, and the total weight by species that all fish in the fish tank represents.

A total of eleven sampling methods were assessed in this study and they were DOS EMS sampling one (S1), DOS EMS sampling two (S2), SFA EMS, oversampling EU, oversampling IOTC, regular sampling EU, regular sampling IOTC, scientific observer programme, logbook, well-map and unloading. From these methods, a number of variables were measured by fish tank or/and fishing trip. *Table 9* shows the number of samples by variables and by fish tank and *Table 10* shows the number of samples by variables and by fishing trip.

Table 9:Variables measured for the eleven sampling methods and the number of samples by fish tanks. YFT: Yellowfin tuna. BET: Bigeye tuna.

<table>
<tr><th></th><th colspan="7">Fish Tank</th></tr>
<tr><th></th><th>Size Frequency Distribution by species</th><th>Total Retained Tuna</th><th>Total Retained Tuna by Species</th><th>Species Composition</th><th>YFT size composition</th><th>BET size composition</th><th>Total Retained Bycatch</th></tr>
<tr><td>DOS EMS S1</td><td>7</td><td>7</td><td>7</td><td>7</td><td>7</td><td>7</td><td></td></tr>
<tr><td>DOS EMS S2</td><td>8</td><td>8</td><td>8</td><td>8</td><td>8</td><td>8</td><td></td></tr>
<tr><td>SFA EMS</td><td></td><td>7</td><td>7</td><td>7</td><td></td><td></td><td></td></tr>
<tr><td>Oversampling EU</td><td rowspan="2">8</td><td>8</td><td>8</td><td>8</td><td>8</td><td>8</td><td>8</td></tr>
<tr><td>Oversampling IOTC</td><td>8</td><td>8</td><td>8</td><td>8</td><td>8</td><td>8</td></tr>
<tr><td>Regular Sampling IOTC</td><td rowspan="2">7</td><td></td><td></td><td>7</td><td>7</td><td>7</td><td></td></tr>
<tr><td>Regular Sampling IOTC</td><td></td><td></td><td>7</td><td>7</td><td>7</td><td></td></tr>
<tr><td>Scientific Observer Programme</td><td></td><td>7</td><td>7</td><td>7</td><td>7</td><td>7</td><td></td></tr>
<tr><td>Logbook</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Well-map</td><td></td><td>8</td><td>8</td><td>8</td><td>8</td><td>8</td><td></td></tr>
<tr><td>Unloading</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 10: Variables measured for the eleven sampling methods and the number of samples by fishing trip. YFT: Yellowfin tuna. BET: Bigeye tuna.

	Fishing Trip									
	Total Retained Tuna	Total Retained Tuna by Species	Species Composition	YFT size composition	BET size composition	Total Discarded Tuna	Total Discarded Tuna by Species	Total Bycatch	Total Retained Bycatch	Total Discarded Bycatch
DOS EMS S1										
DOS EMS S2										
SFA EMS	8	8	8					8		
Oversampling EU										
Oversampling IOTC										
Regular Sampling IOTC										
Regular Sampling IOTC										
Scientific Observer Programme	9	9	9			1	1	9	9	9
Logbook	10	10	10	10	10					
Well-map	10	10	10	10	10					
Unloading	10	10	10	10	10					

2.4 Data Analysis

2.4.1 Comparison of Catch for Retained Tuna

Total retained tuna and total retained tuna by species estimated by fish tank (*Table 11*) and total retained tuna and total retained tuna by species estimated by trip (*Table 12*) were compared among different sampling methods. To test the agreement between two sampling methods for each of the four variables, the concordance analysis was used. This is a statistical method used for assessing agreement between two series of measurements. It checks if both series of measurements agree (are identical) or not and to what extent (Carrasco & Jover, 2004).

Table 11: Variables measured for the seven sampling methods and the number of samples for total retained tuna and total retained tuna by species by fish tank.

	DOS EMS S1	DOS EMS S2	SFA EMS	Oversampling EU	Oversampling IOTC	Scientific Observer Programme	Well-map
DOS EMS S1							
DOS EMS S2	7						
SFA EMS	7	7					
Oversampling EU	7	8	7				
Oversampling IOTC	7	8	7				
Scientific Observer Programme	6	7	6	7	7		
Well-map	7	8	7	8	8	7	

Table 12: Variables measured for the five sampling methods and the number of samples for total retained tuna and total retained tuna by species by fishing trip.

	SFA EMS	Scientific Observer Programme	Logbook	Well-map	Unloading
SFA EMS					
Scientific Observer Programme	7				
Logbook	8	9			
Well-map	8	9	10		
Unloading	8	9	10	10	

Three tests were performed in the concordance analysis and they were Concordance Correlation Coefficient, Intraclass Correlation Coefficient and Bland and Altman method.

Concordance Correlation Coefficient (CCC): According to Lin (1989) concordance correlation coefficient is for measuring agreement between continuous variables (X and Y). The values of CCC lies between -1 and +1. A value equal to +1 corresponds to perfect agreement between two measurement methods. A value equal to 0 indicates that the two methods are independent to one another. Furthermore, in theory, this statistic can also take negative values. A value equal to -1 indicates a perfect mismatch between the two methods (Carrasco & Jover, 2004).

Intraclass Correlation Coefficient (ICC): ICC quantifies the concordance between different measurements of a numerical variable. This coefficient estimates the average of the correlations between all possible ordinations of pairs of available observations. The value of ICC ranges from 0 to 1. Therefore, the maximum possible match corresponds to a value of ICC = 1. In this case, all observed variability would be explained by the differences between subjects and not by the differences between the measurement methods. On the other hand, the value ICC = 0 is obtained when the observed concordance is equal to the one that would be expected to occur only by chance (Fernández & Díaz, 2004). *Table 13* below explain how to interpret ICC values.

Table 13: Assessing concordance according to the values of Intraclass Correlation Coefficient (ICC) (Pita Fernández & Pértegas Díaz, 2004).

Values of ICC	Strength of the concordance
>0.90	very good
0.71 - 0.90	good
0.51 - 0.70	moderate
0.31 - 0.50	average
<0.30	Poor or invalid

Bland and Altman method (B&A): A first exploratory approach, was to represent graphically the two methods through a diagram of dispersion, where each point represents the pair of measures obtained from each individual. If the concordance is perfect, all points would be located on the bisector (Y = X) (Carrasco & Jover, 2004). The Bland and Altman method is another simple graphical procedure to evaluate the concordance between two measurement systems (Pita Fernández & Pértegas Díaz, 2004). It is a method to quantify agreement between two quantitative measurements by constructing limits of agreement. These statistical limits are calculated by using the mean and the standard deviation (s) of the differences between two measurements. The resulting graph is a scatter plot XY, in which the Y axis shows the difference between the two paired measurements (A-B) and the X axis represents the average of these measures ((A+B)/2). In other words, the difference of the two paired measurements is plotted against the mean of the two measurements (Giavarina, 2015). The mean of the two measurements can be understood as an approximation to the real value, since the measuring error of the two measurement systems would be attenuated. Bland and Altman recommended that 95% of the data points should lie within $\pm 2s$ of the mean difference. The 95% limits of concordance allow to identify the most discordant individuals (Carrasco & Jover, 2004).

2.4.2 Comparison of Species and Size Composition for Retained Tuna

The species composition of the catch (i.e. proportions of the total catch by species) and size composition of the catch (i.e. proportions of the total catch by commercial size category, +10 kg and -10 kg) by species (yellowfin tuna and bigeye tuna) estimated by fish tank (*Table 14 and Table 15*) by trip (*Table 16 and Table 17*) were compared among different sampling methods. To test for differences in the proportion of the catch, the Chi-square test through contingency tables of total catch by species versus the method of sampling was used (Heuer & Perkins, n.d.). This is used to investigate whether two categorical variables are independent. It measures how close observed frequencies are to expected frequencies. A small chi-square statistic means that observed data fits extremely well with expected data, thus, there is a relationship, whereas a large chi-square statistic means that observed frequencies and expected frequencies are far apart and there is no relationship (Heuer & Perkins, n.d.). Furthermore, the Monte Carlo algorithms was used to provide an estimate of the exact P-value called the Monte Carlo P-value. Monte Carlo estimates involve enumerating a random subset of all of the possible outcomes in the reference set. The random subset is large (default = 10,000) and can be set at any size. Increasing the size of the random subset will increase the accuracy of the Monte Carlo estimation. The Monte Carlo method therefore provides a reliable, robust method of estimating the exact P-value (Heuer & Perkins, n.d.). Data was compared tank by tank comparing only two methods in each test.

Table 14: Variables measured for the nine sampling methods and the number of samples for species composition by fish tank.

	DOS EMS S1	DOS EMS S2	SFA EMS	Oversampling EU	Oversampling IOTC	Regular Sampling EU	Regular Sampling IOTC	Scientific Observer Programme	Well-map
DOS EMS S1									
DOS EMS S2	7								
SFA EMS	7	7							
Oversampling EU	7	8	7						
Oversampling IOTC	7	8	7						
Regular Sampling EU	6	7	6	7					
Regular Sampling IOTC	6	7	6		7				
Scientific Observer Programme	6	7	6	7	7	6	6		
Well-map	7	8	7	8	8	7	7	7	

Table 15: Variables measured for the eight sampling methods and the number of samples for yellowfin tuna size composition and bigeye tuna size composition by fish tank.

	DOS EMS S1	DOS EMS S2	Oversampling EU	Oversampling IOTC	Regular Sampling EU	Regular Sampling IOTC	Scientific Observer Programme	Well-map
DOS EMS S1								
DOS EMS S2	7							
Oversampling EU	7	8						
Oversampling IOTC	7	8						
Regular Sampling EU	6	7	7					
Regular Sampling IOTC	6	7		7				
Scientific Observer Programme	6	7	7	7	6	6		
Well-map	7	8	8	8	7	7	7	

Table 16: Variables measured for the five sampling methods and the number of samples for species composition by fishing trip.

	SFA EMS	Scientific Observer Programme	Logbook	Well-map	Unloading
SFA EMS					
Scientific Observer Programme	7				
Logbook	8	9			
Well-map	8	9	10		
Unloading	8	9	10	10	

Table 17: Variables measured for the three sampling methods and the number of samples for yellowfin tuna size composition and bigeye tuna size composition by fishing trip.

	Logbook	Well-map	Unloading
Logbook			
Well-map	10		
Unloading	10	10	

2.4.3 Comparison of Fish Size Distributions for Retained Tuna

The fish size distribution of the catch of skipjack tuna, yellowfin tuna and bigeye tuna estimated by fish tank was compared among different sampling methods (*Table 18*). To test for significant differences in the fish size distribution estimated by each method, the Kolmogorov-Smirnov test was used (Conover, 1971). This is a nonparametric test which compares the cumulative distributions of two data sets. It tries to determine if two datasets differ significantly, thereby data was compared tank by tank comparing only two methods in each test.

Table 18: Variables measured for the four sampling methods and the number of samples for fish size distribution of the catch of skipjack tuna, yellowfin tuna and bigeye tuna by fish tank.

	DOS EMS S1	DOS EMS S2	Oversampling	Regular Sampling
DOS EMS S1				
DOS EMS S2	7			
Oversampling	7	8		
Regular Sampling	6	7	7	

3 Results

3.1 Comparison of Catch for Retained Tuna

Comparison between Oversampling EU and Oversampling IOTC with DOS EMS S1

The agreement between oversampling EU and DOS EMS S1 and between oversampling IOTC and DOS EMS S1 for total retained tuna catch by fish tank was moderate. The B&A test revealed that on average DOS EMS S1 measured 13.6 MT (*Table 19*) less than oversampling EU which represents 16.42% of the total average tuna catches in the tank. It also showed that on average DOS EMS S1 measured 7.114 MT (*Table 20*) less than oversampling IOTC representing 9.96% of total average tuna catches in the tank. Both B&A plots (*Figure 9 and Figure 10*), showed the difference between the two methods had a negative linear trend that is, the difference decreases with the magnitude of the measurement. Therefore, the main source of error between the two methods referred to systematic error.

The agreement between oversampling EU and DOS EMS S1 and between oversampling IOTC and DOS EMS S1 for skipjack tuna by fish tank was good. The B&A test revealed that on average DOS EMS S1 measured 4.37 MT (*Table 21*) less than oversampling EU which represents 15.26% of the total average skipjack tuna catches in the tank. It also showed that on average DOS EMS S1 measured 1.214 MT (*Table 22*) more than oversampling IOTC representing 0.33% of total average skipjack tuna catches in the tank. Both B&A plots (*Figure 11 and Figure 12*), showed there was no relationship between measurement error and the true value. Therefore, the main source of error between the two methods was random.

The agreement between oversampling EU and DOS EMS S1 and between oversampling IOTC and DOS EMS S1 for yellowfin tuna by fish tank was good. The B&A test revealed that on average DOS EMS S1 measured 5.357 MT (*Table 23*) less than oversampling EU which represents 17.04% of the total average yellowfin tuna catches in the tank. It also showed that on average DOS EMS S1 measured 5.243 MT (*Table 24*) less than oversampling IOTC representing 16.79% of total average yellowfin tuna catches in the tank. Both B&A plots (*Figure 13 and Figure 14*), showed there was no relationship between measurement error and the true value. Therefore, the main source of error between the two methods was random.

There was no agreement between oversampling EU and DOS EMS S1 and between oversampling IOTC and DOS EMS S1 for bigeye tuna by fish tank. The B&A test revealed that on average DOS EMS S1 measured 3.914 MT (*Table 25*) less than oversampling EU which represents 29.62% of the total average bigeye tuna catches in the tank. It also showed that on average DOS EMS S1 measured 3.214 MT (*Table 26*) less than oversampling IOTC representing 23.45% of total average bigeye tuna catches in the tank. Both B&A plots (*Figure 15 and Figure 16*), showed the difference between the two methods had a negative linear trend that is, the difference decreases with the magnitude of the measurement. Therefore, the main source of error between the two methods referred to systematic error.

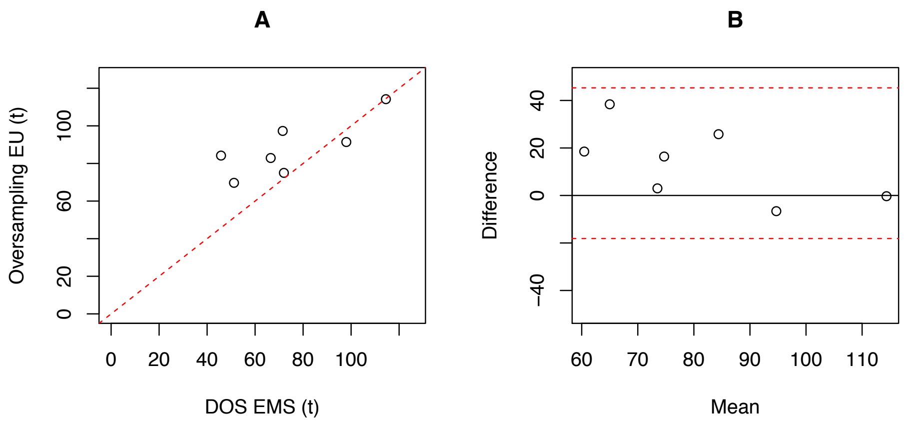


Figure 9: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by fish tank for Oversampling EU and DOS EMS S1 procedures.

Table 19: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by fish tank for Oversampling EU and DOS EMS S1 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.549	0.027	0.836
ICC	0.553	-0.192	0.904
B&A	13.6	-18.121	45.321

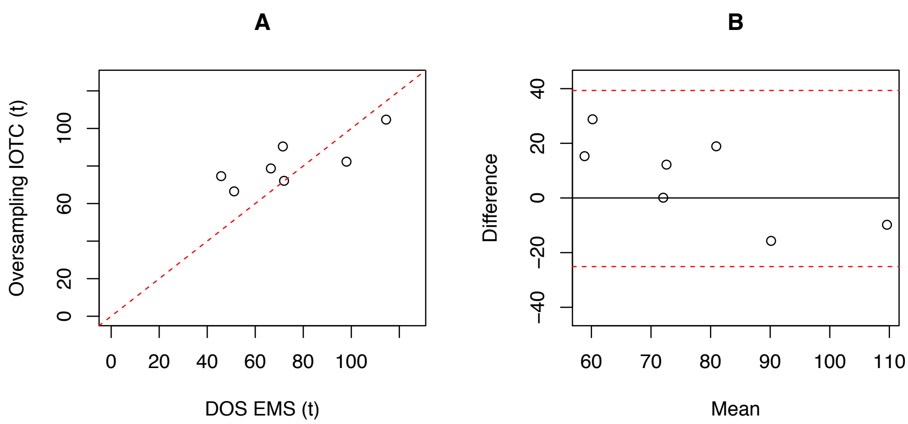


Figure 10: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by fish tank for Oversampling IOTC and DOS EMS S1 procedures.

Table 20: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained tuna catch by fish tank for Oversampling IOTC and DOS EMS S1 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.613	0.139	0.858
ICC	0.646	-0.049	0.927
B&A	7.114	-25.112	39.341

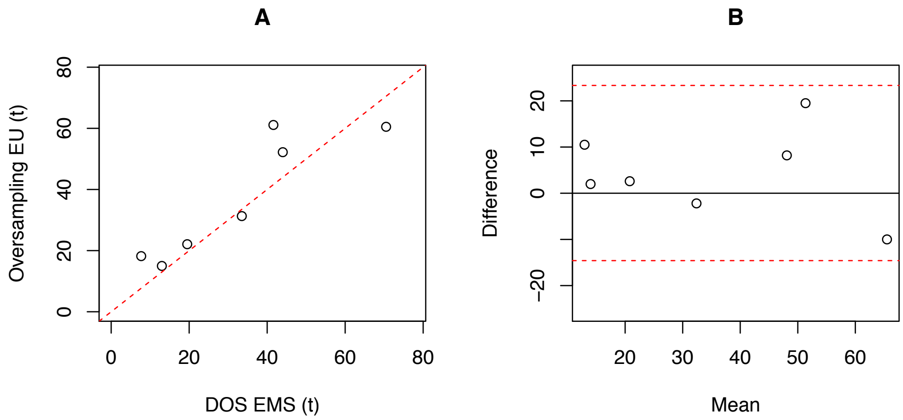


Figure 11: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by fish tank for Oversampling EU and DOS EMS S1 procedures.

Table 21: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by fish tank for Oversampling EU and DOS EMS S1 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.876	0.472	0.976
ICC	0.891	0.545	0.980
B&A	4.37	-14.597	23.337

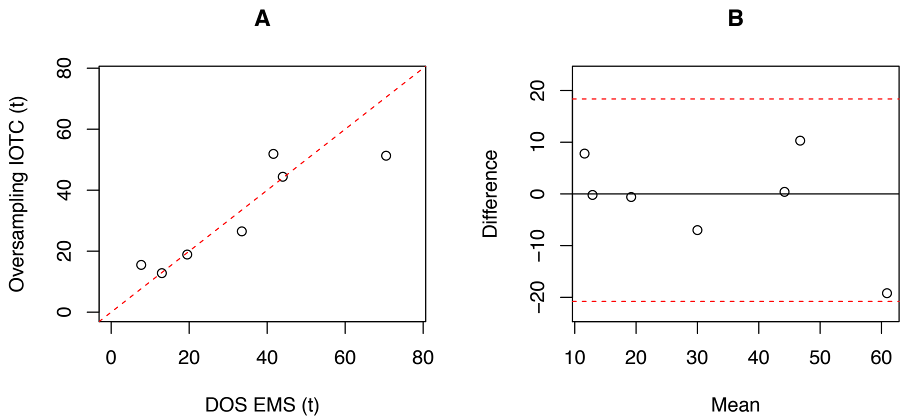


Figure 12: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) total retained skipjack tuna (SKJ) catch by fish tank for Oversampling IOTC and DOS EMS S1 procedures.

Table 22: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by fish tank for Oversampling IOTC and DOS EMS S1 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.873	0.518	0.971
ICC	0.890	0.540	0.980
B&A	-1.214	-20.790	18.361

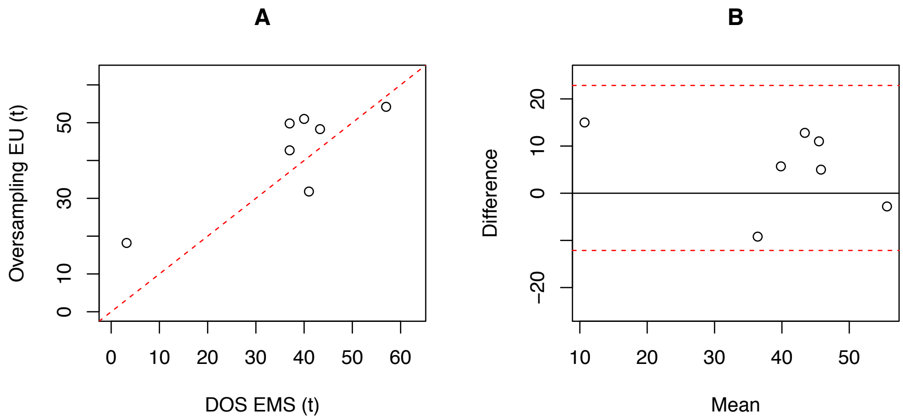


Figure 13: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by fish tank for Oversampling EU and DOS EMS S1 procedures.

Table 23: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by fish tank for Oversampling EU and DOS EMS S1 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.765	0.245	0.943
ICC	0.787	0.243	0.959
B&A	5.357	-12.134	22.848

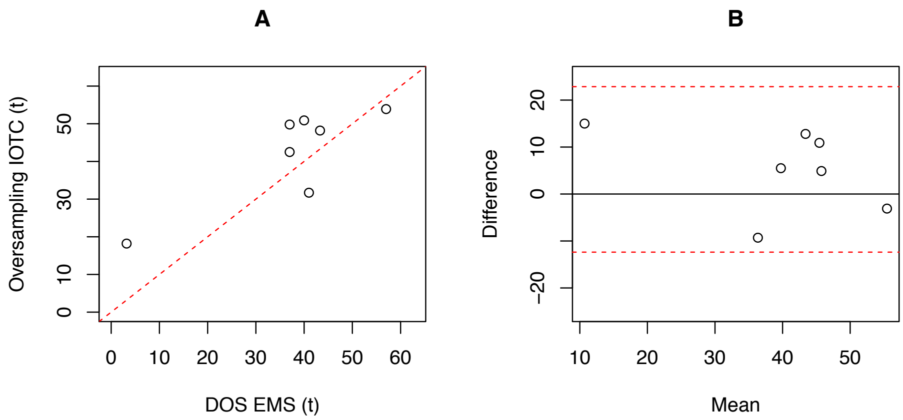


Figure 14: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by fish tank for Oversampling IOTC and DOS EMS S1 procedures.

Table 24: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by fish tank for Oversampling IOTC and DOS EMS S1 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.764	0.242	0.943
ICC	0.787	0.242	0.959
B&A	5.243	-12.375	22.861

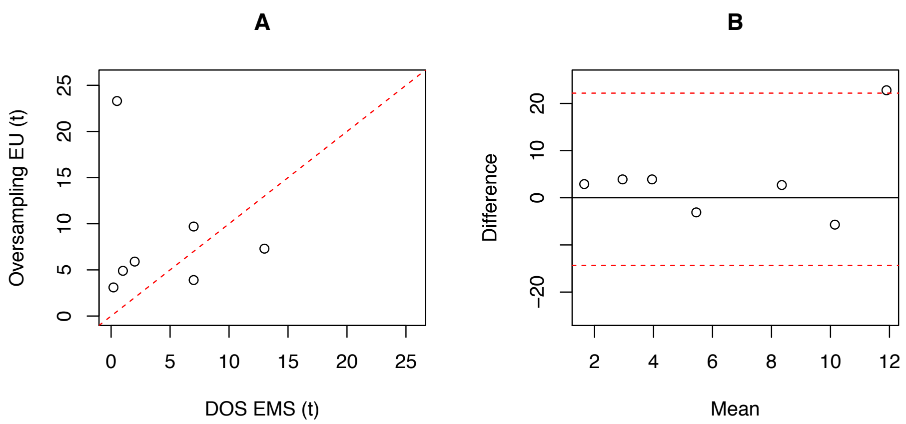


Figure 15: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by fish tank for Oversampling EU and DOS EMS S1 procedures.

Table 25: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by fish tank for Oversampling EU and DOS EMS S1 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	-0.133	-0.660	0.481
ICC	-0.186	-0.763	0.593
B&A	3.914	-14.358	22.186

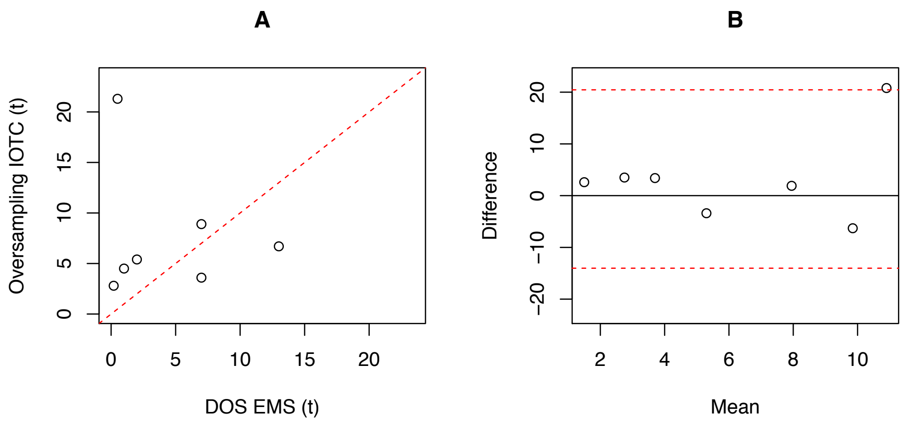


Figure 16: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by fish tank for Oversampling IOTC and DOS EMS S1 procedures.

Table 26: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by fish tank for Oversampling IOTC and DOS EMS S1 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	-0.142	-0.693	0.514
ICC	-0.167	-0.755	0.605
B&A	3.214	-14.024	20.453

Comparison between Oversampling EU and Oversampling IOTC with Well-map

The agreement between oversampling EU and well-map was average and between oversampling IOTC and well-map was moderate for total retained tuna catch by fish tank. The B&A test revealed that on average well-map measured 7.725 MT (*Table 27*) less than oversampling EU which represents 7.8% of the total average tuna catches in the tank. It also showed that on average well-map measured 1.113 MT (*Table 28*) less than oversampling IOTC representing 0.27% of total average tuna catches in the tank. Both B&A plots (*Figure 17 and Figure 18*), showed there was no relationship between measurement error and the true value. Therefore, the main source of error between the two methods was random.

The agreement between oversampling EU and well-map was good and between oversampling IOTC and well-map was moderate for skipjack tuna by fish tank. The B&A test revealed that on average well-map measured 2.264 MT (*Table 29*) more than oversampling EU which represents 13.81% of the total average skipjack tuna catches in the tank. It also showed that on average well-map measured 8.05 MT (*Table 30*) more than oversampling IOTC representing 33.69% of total average skipjack tuna catches in the tank. Both B&A plots (*Figure 19 and Figure 20*), showed there was no relationship between measurement error and the true value. Therefore, the main source of error between the two methods was random.

The agreement between oversampling EU and well-map and between oversampling IOTC and well-map for yellowfin tuna by fish tank was average. The B&A test revealed that on average well-map measured 8.738 MT (*Table 31*) less than oversampling EU which represents 18.12% of the total average yellowfin tuna catches in the tank. It also showed that on average well-map measured 8.625 MT (*Table 32*) less than oversampling IOTC representing 17.85% of total average yellowfin tuna catches in the tank. Both B&A plots (*Figure 21 and Figure 22*), showed there was no relationship between measurement error and the true value. Therefore, the main source of error between the two methods was random.

There was no agreement between oversampling EU and well-map and between oversampling IOTC and well-map for bigeye tuna by fish tank. The B&A test revealed that on average well-map measured 1.35 MT (*Table 33*) less than oversampling EU which represents 13.11% of the total average bigeye tuna catches in the tank. It also showed that on average well-map measured 0.713 MT (*Table 34*) less than oversampling IOTC representing 23.52% of total average bigeye tuna catches in the tank. Both B&A plots (*Figure 23 and Figure 24*), showed there was no relationship between measurement error and the true value. Therefore, the main source of error between the two methods was random.

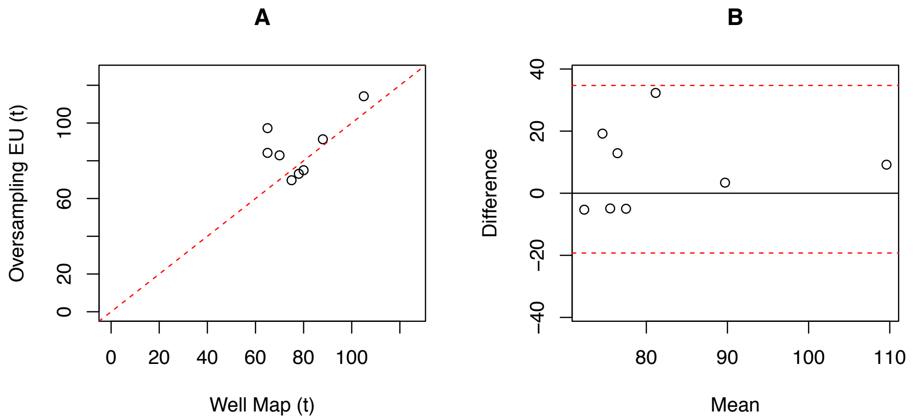


Figure 17: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by fish tank for Oversampling EU and Well-map procedures.

Table 27: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by fish tank for Oversampling EU and Well-map procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.459	-0.189	0.829
ICC	0.470	-0.241	0.863
B&A	7.725	-19.259	34.709

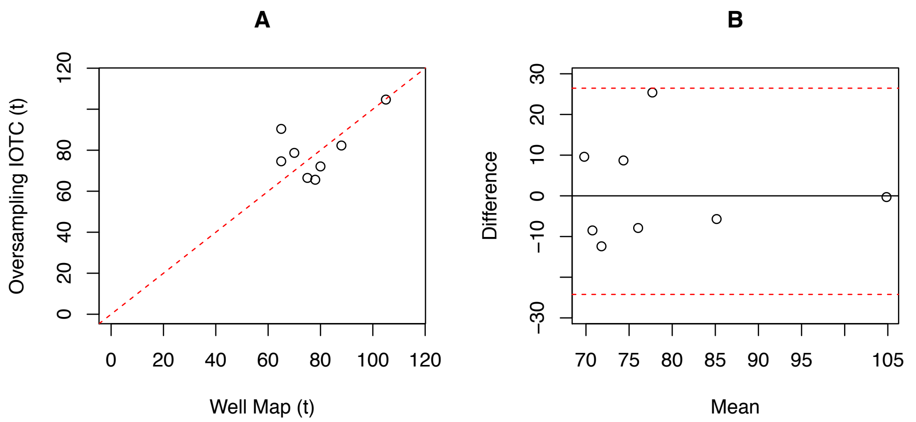


Figure 18: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by fish tank for Oversampling IOTC and Well-map procedures.

Table 28: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by fish tank for Oversampling IOTC and Well-map procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.538	-0.193	0.885
ICC	0.583	-0.088	0.898
B&A	1.113	-24.232	26.457

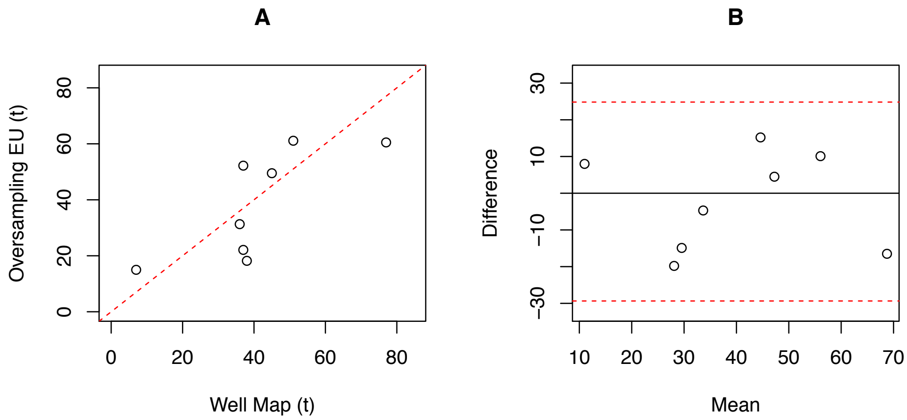


Figure 19: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by fish tank for Oversampling EU and Well-map procedures.

Table 29: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by fish tank for Oversampling EU and Well-map. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.748	0.172	0.943
ICC	0.775	0.271	0.945
B&A	-2.264	-29.357	24.829

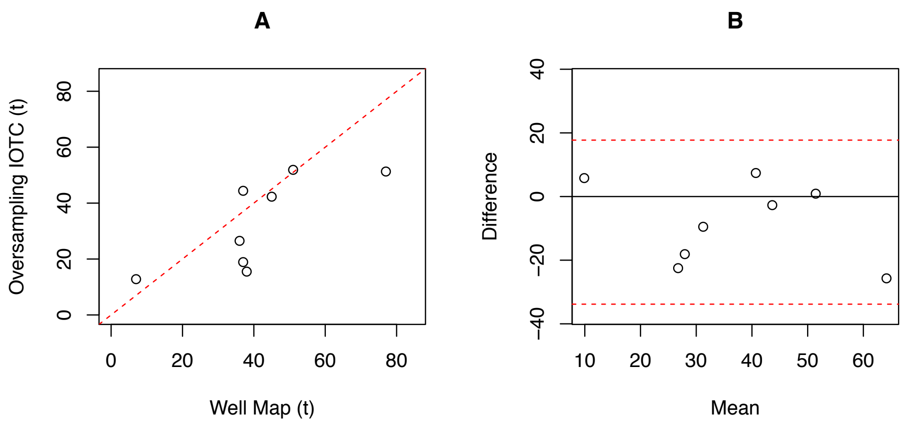


Figure 20: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by fish tank for Oversampling IOTC and Well-map procedures.

Table 30: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by fish tank for Oversampling IOTC and Well-map procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.665	0.098	0.906
ICC	0.684	0.081	0.926
B&A	-8.05	-33.826	17.726

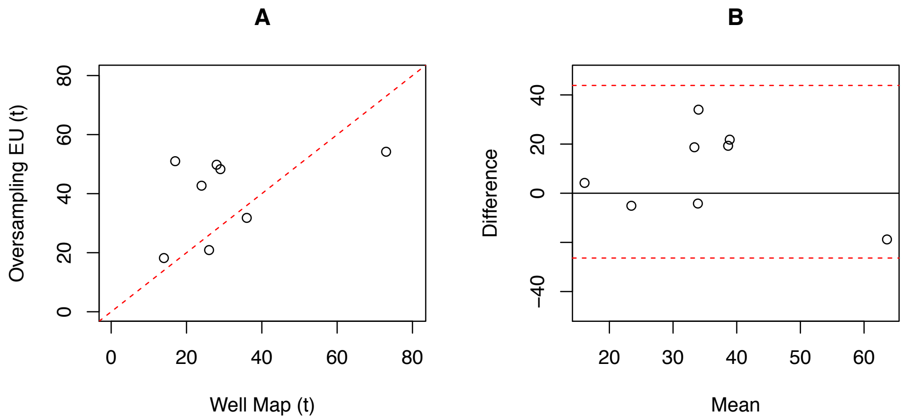


Figure 21: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by fish tank for Oversampling EU and Well-map procedures.

Table 31: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by fish tank for Oversampling EU and Well-map procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.367	-0.277	0.784
ICC	0.378	-0.343	0.831
B&A	8.738	-26.374	43.849

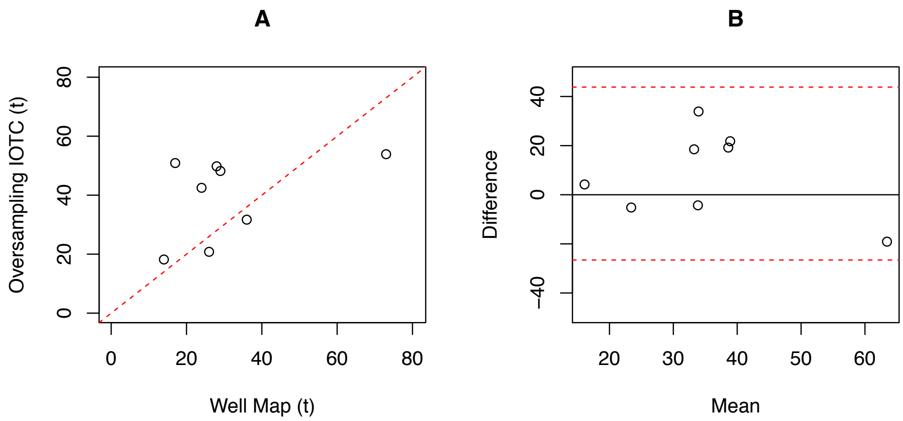


Figure 22: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by fish tank for Oversampling IOTC and Well-map procedures.

Table 32: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by fish tank for Oversampling IOTC and Well-map procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.365	-0.281	0.783
ICC	0.377	-0.345	0.831
B&A	8.625	-26.574	43.824

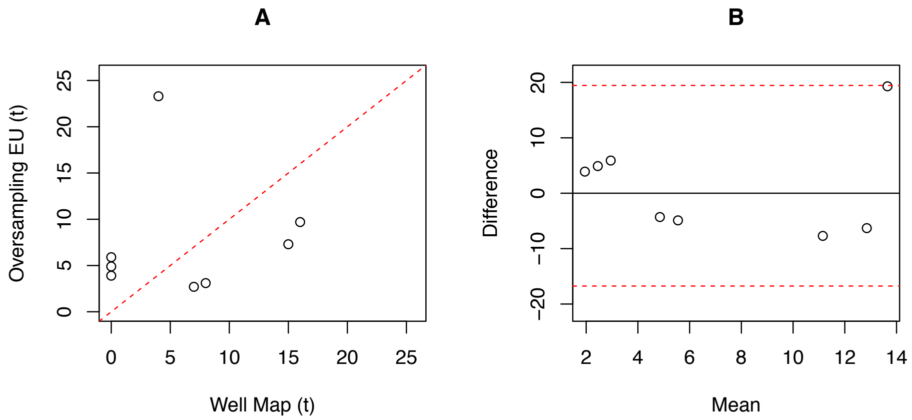


Figure 23: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by fish tank for Oversampling EU and Well-map procedures.

Table 33: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by fish tank for Oversampling EU and Well-map procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.068	-0.612	0.691
ICC	0.124	-0.559	0.725
B&A	1.35	-16.752	19.452

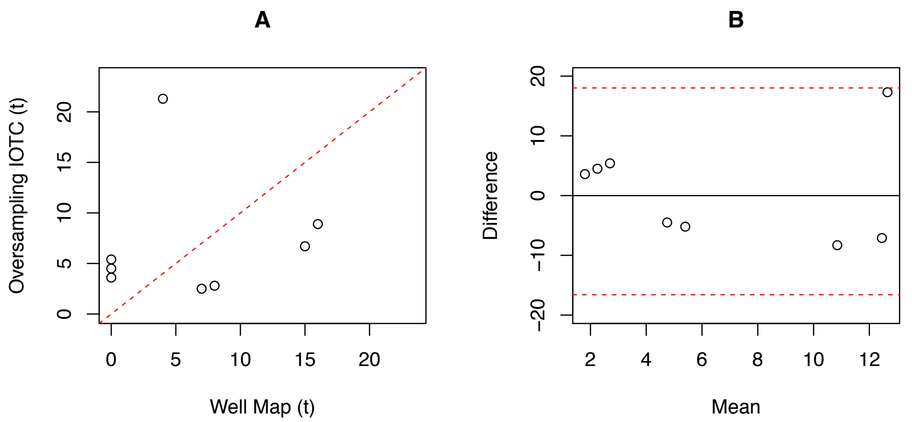


Figure 24: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by fish tank for Oversampling IOTC and Well-map procedures.

Table 34: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by fish tank for Oversampling IOTC and Well-map procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.070	-0.619	0.698
ICC	0.133	-0.552	0.730
B&A	0.713	-16.595	18.020

Comparison between Unloading and SFA EMS

The agreement between unloading and SFA EMS for total retained tuna catch by trip was moderate. The B&A test revealed that on average SFA EMS measured 261.375 MT (*Table 35*) less than unloading which represents 16.25% of the total average tuna catches by trip. Furthermore, the B&A plot showed the difference between the two methods had a positive linear trend (*Figure 25*), that is, the difference increases with the magnitude of the measurement. Therefore, the main source of error between the two methods referred to systematic error.

The agreement between unloading and SFA EMS for skipjack tuna by trip was good. The B&A test revealed that on average SFA EMS measured 80.146 MT (*Table 36*) less than unloading which represents 4.72% of the total average skipjack tuna catches by trip. Furthermore, the B&A plot showed the difference between the two methods had a positive linear trend (*Figure 26*), that is, the difference increases with the magnitude of the measurement. Therefore, the main source of error between the two methods referred to systematic error.

The agreement between unloading and SFA EMS for yellowfin tuna by trip was average. The B&A test revealed that on average SFA EMS measured 161.242 MT (*Table 37*) less than unloading which represents 23.53% of the total average yellowfin tuna catches by trip. Furthermore, the B&A plot showed there was no relationship between measurement error and the true value (*Figure 27*). Therefore, the main source of error between the two methods was random.

There was no agreement between unloading and SFA EMS for bigeye tuna by trip. The B&A test revealed that on average SFA EMS measured 18.873 MT (*Table 38*) more than unloading which represents a very insignificant amount of the total average bigeye tuna catches by trip. Furthermore, the B&A plot showed there was no relationship between measurement error and the true value (*Figure 28*). Therefore, the main source of error between the two methods was random.

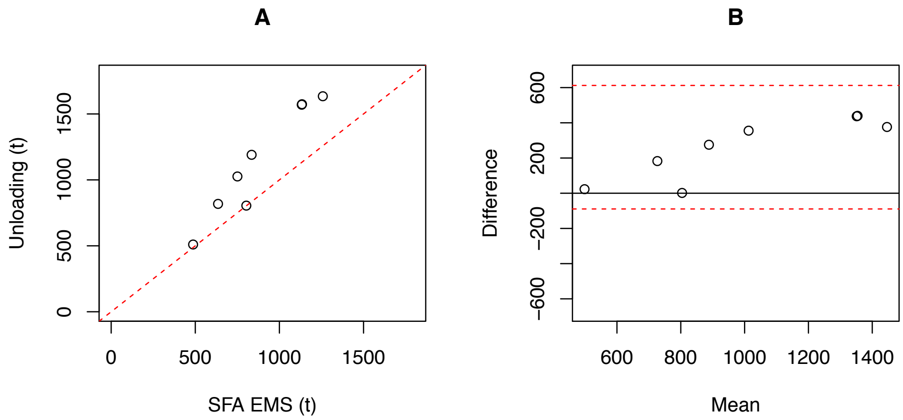


Figure 25: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by trip for Unloading and SFA EMS procedures.

Table 35: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by trip for Unloading and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.669	0.322	0.858
ICC	0.664	0.044	0.921
B&A	261.375	-89.405	612.155

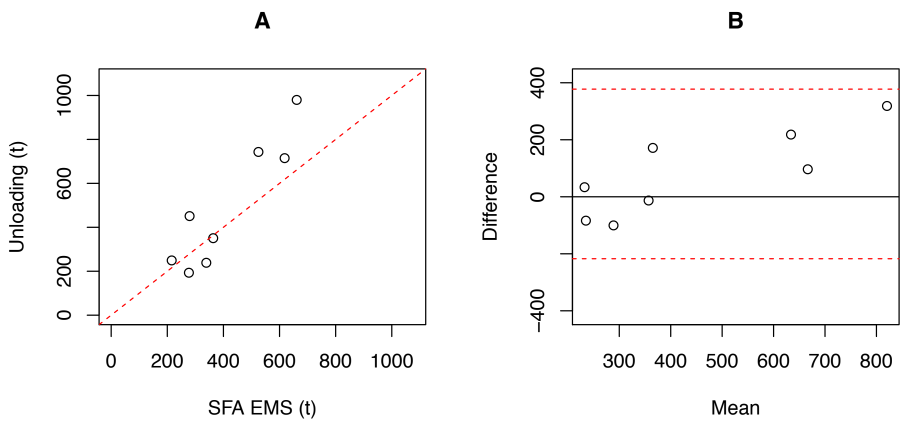


Figure 26: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by trip for Unloading and SFA EMS procedures.

Table 36: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by trip for Unloading and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.753	0.445	0.902
ICC	0.773	0.267	0.949
B&A	80.146	-217.338	377.630

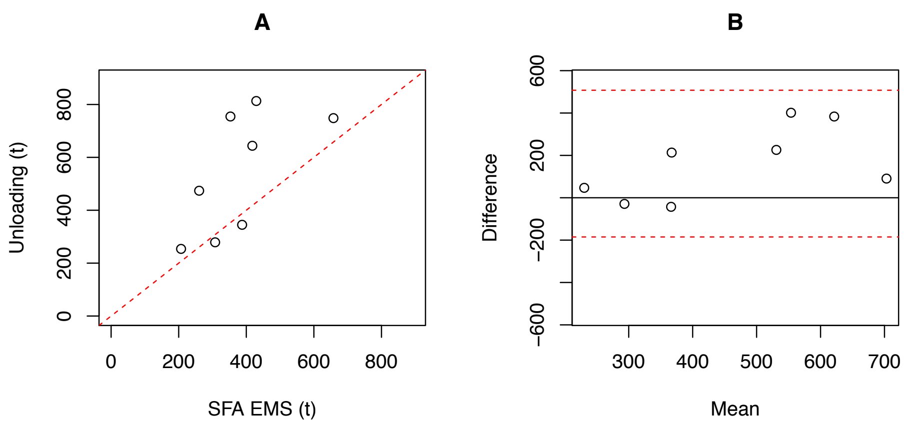


Figure 27: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by trip for Unloading and SFA EMS procedures.

Table 37: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by trip for Unloading and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.409	-0.065	0.732
ICC	0.366	-0.355	0.827
B&A	161.242	-185.077	507.560

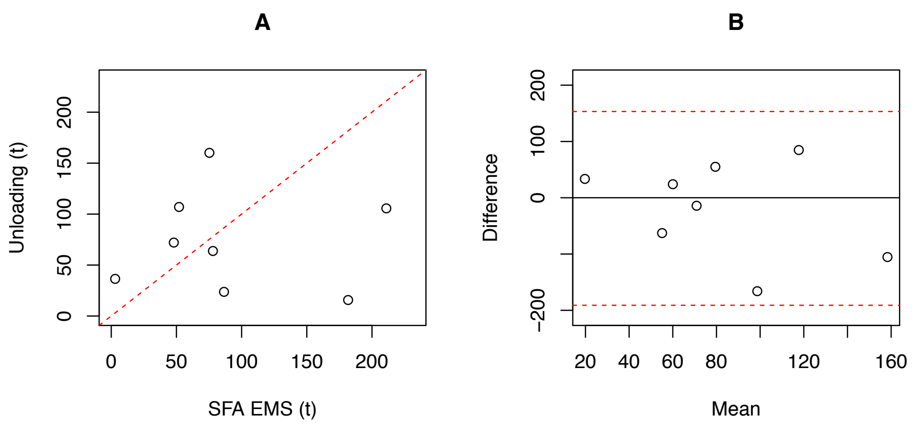


Figure 28: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by trip for Unloading and SFA EMS procedures.

Table 38: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained bigeye tuna (BET) catch by trip for Unloading and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	-0.014	-0.622	0.604
ICC	0.025	-0.623	0.675
B&A	-18.873	-191.031	153.285

Comparison between Unloading and Logbook

The agreement between unloading and logbook for total retained tuna catch by trip was very good. The B&A test revealed that on average logbook measured 75.2 MT (*Table 39*) less than unloading which represents 6.38% of the total average tuna catches by trip. The B&A plot revealed one discordant individual beyond the 95% limits of concordance (*Figure 29*). Furthermore, there was no relationship between measurement error and the true value. Therefore, the main source of error between the two methods was random.

The agreement between unloading and logbook for skipjack tuna by trip was very good. The B&A test revealed that on average logbook measured 50.049 MT (*Table 40*) more than unloading which represents 13.03% of the total average skipjack tuna catches by trip. Furthermore, the B&A plot (*Figure 30*), showed the difference between the two methods had a negative linear trend that is, the difference decreases with the magnitude of the measurement. Therefore, the main source of error between the two methods referred to systematic error.

The agreement between unloading and logbook for yellowfin tuna by trip was good. The B&A test revealed that on average logbook measured 146.686 MT (*Table 41*) less than unloading which represents 62.38% of the total average yellowfin tuna catches by trip. Furthermore, the B&A plot (*Figure 31*), showed the difference between the two methods had a negative linear trend that is, the difference decreases with the magnitude of the measurement. Therefore, the main source of error between the two methods referred to systematic error.

The agreement between unloading and logbook for bigeye tuna by trip was average. The B&A test revealed that on average logbook measured 58.521 MT (*Table 42*) more than unloading which represents 30.92% of the total average bigeye tuna catches by trip. Furthermore, the B&A plot showed the difference between the two methods had a positive linear trend (*Figure 32*), that is, the difference increases with the magnitude of the measurement. Therefore, the main source of error between the two methods referred to systematic error.

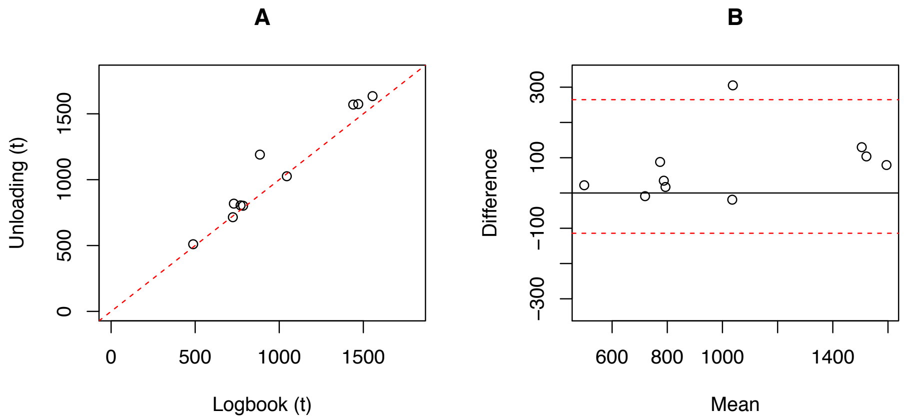


Figure 29: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by trip for Unloading and Logbook procedures.

Table 39: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by trip for Unloading and Logbook procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.951	0.838	0.986
ICC	0.955	0.840	0.988
B&A	75.2	-114.173	264.573

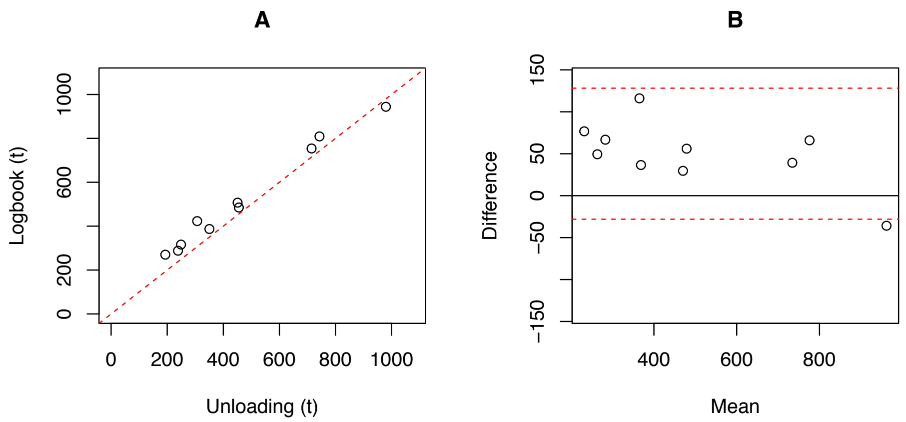


Figure 30: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by trip for Unloading and Logbook procedures.

Table 40: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by trip for Unloading and Logbook procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.966	0.901	0.989
ICC	0.969	0.888	0.992
B&A	50.049	-28.068	128.167

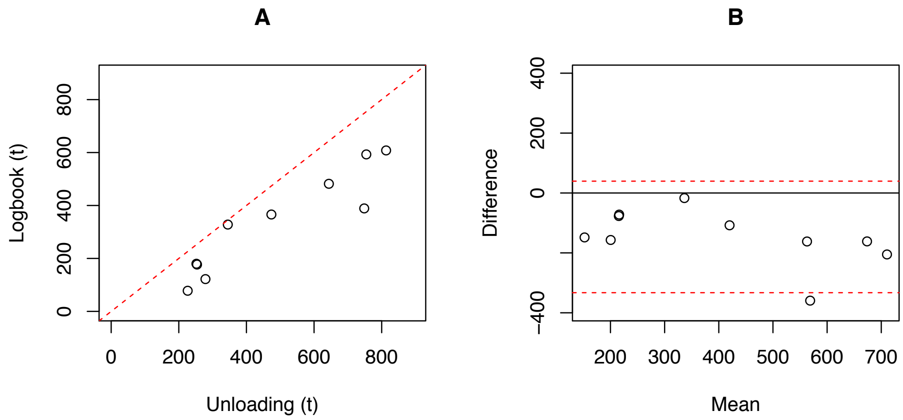


Figure 31: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by trip for Unloading and Logbook procedures.

Table 41: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by trip for Unloading and Logbook procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.722	0.399	0.885
ICC	0.717	0.232	0.920
B&A	-146.686	-332.870	39.498

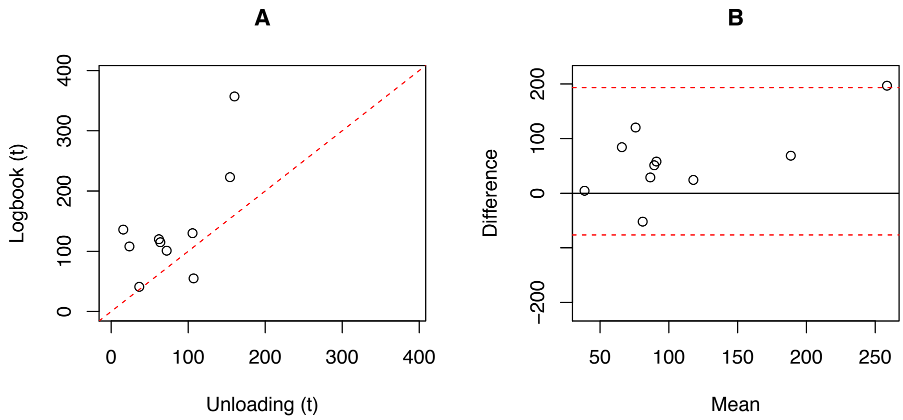


Figure 32: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by trip for Unloading and Logbook procedures.

Table 42: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained bigeye tuna (BET) catch by trip for Unloading and Logbook procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.431	0.030	0.712
ICC	0.391	-0.246	0.801
B&A	58.521	-76.397	193.439

Comparison between Unloading and Well-map

The agreement between unloading and well-map for total retained tuna catch by trip was very good. The B&A test revealed that on average well-map measured 79.4 MT (*Table 43*) less than unloading which represents 6.33% of the total average tuna catches by trip. Furthermore, the B&A plot showed there was no relationship between measurement error and the true value (*Figure 33*). Therefore, the main source of error between the two methods was random.

The agreement between unloading and well-map for skipjack tuna by trip was very good. The B&A test revealed that on average well-map measured 48.349 MT (*Table 44*) more than unloading which represents 13.06% of the total average skipjack tuna catches by trip. Furthermore, the B&A plot (*Figure 34*), showed the difference between the two methods had a negative linear trend that is, the difference decreases with the magnitude of the measurement. Therefore, the main source of error between the two methods referred to systematic error.

The agreement between unloading and well-map for yellowfin tuna by trip was good. The B&A test revealed that on average well-map measured 145.586 MT (*Table 45*) less than unloading which represents 59.11% of the total average yellowfin tuna catches by trip. Furthermore, the B&A plot (*Figure 35*), showed the difference between the two methods had a negative linear trend that is, the difference decreases with the magnitude of the measurement. Therefore, the main source of error between the two methods referred to systematic error.

The agreement between unloading and well-map for bigeye tuna by trip was average. The B&A test revealed that on average well-map measured 54.921 MT (*Table 46*) more than unloading which represents 28.56% of the total average bigeye tuna catches by trip. Furthermore, the B&A plot showed the difference between the two methods had a positive linear trend (*Figure 36*), that is, the difference increases with the magnitude of the measurement. Therefore, the main source of error between the two methods referred to systematic error.

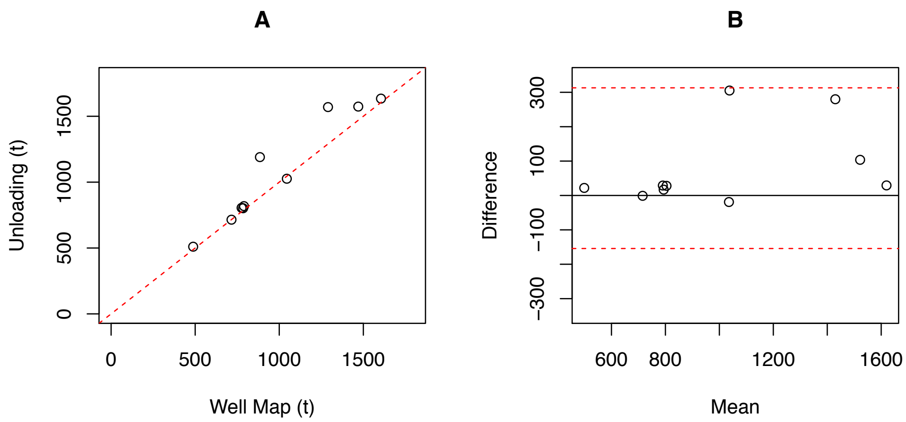


Figure 33: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by trip for Unloading and Well-map procedures.

Table 43: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by trip for Unloading and Well-map procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.932	0.780	0.980
ICC	0.937	0.782	0.984
B&A	79.4	-154.232	313.032

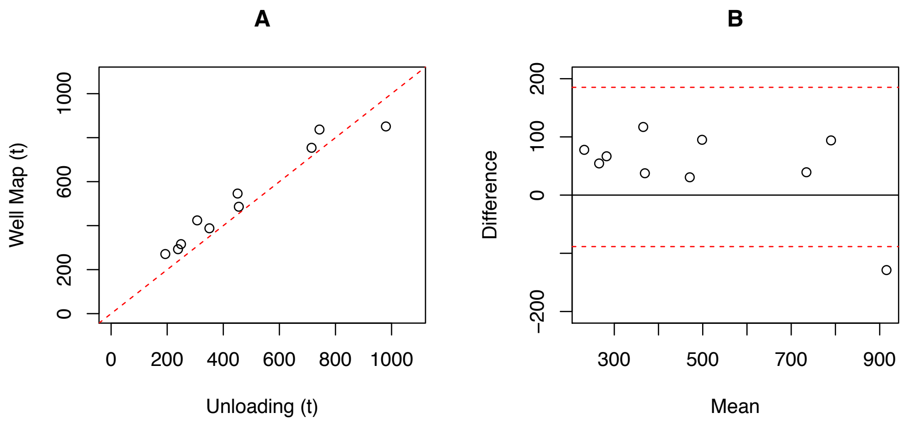


Figure 34: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by trip for Unloading and Well-map procedures.

Table 44: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by trip for Unloading and Well-map procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.940	0.818	0.981
ICC	0.945	0.807	0.986
B&A	48.349	-88.486	185.185

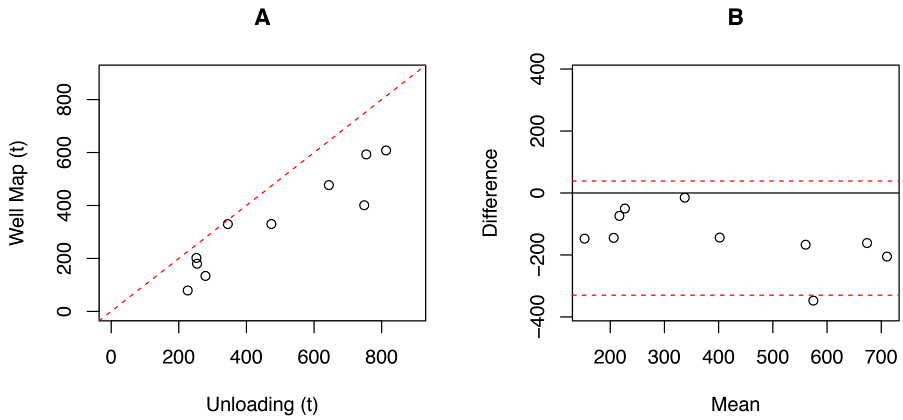


Figure 35: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by trip for Unloading and Well-map procedures.

Table 45: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by trip for Unloading and Well-map procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.722	0.405	0.884
ICC	0.717	0.232	0.920
B&A	-145.586	-329.750	38.578

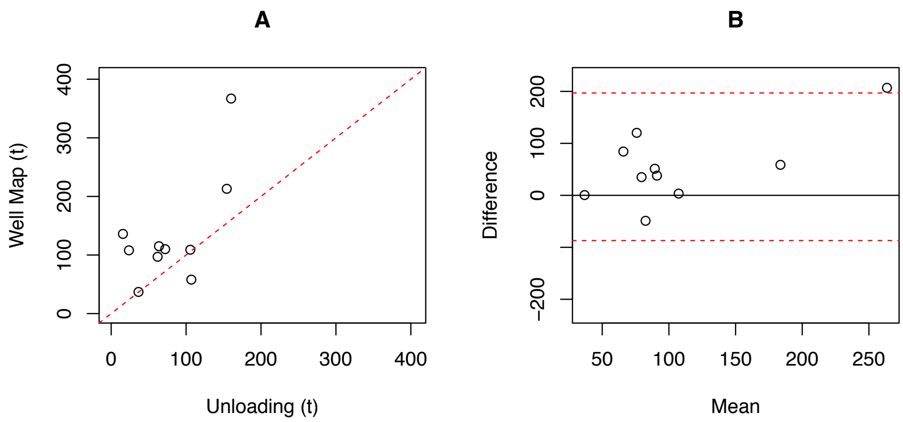


Figure 36: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by trip for Unloading and Well-map procedures.

Table 46: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained bigeye tuna (BET) catch by trip for Unloading and Well-map procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.431	0.022	0.716
ICC	0.403	-0.234	0.806
B&A	54.921	-87.066	196.908

3.2 Comparison of Species and Size Composition for Retained Tuna

Comparison between Oversampling EU and Oversampling IOTC with DOS EMS S1

The comparisons yield 71% of good results between oversampling EU and DOS EMS S1 and between oversampling IOTC and DOS EMS S1 for proportion of tuna species, with significant differences between the methods for two of the seven fish tanks (Tank 1 and Tank 8) (*Table 47*). The general trend that is shown on the graphs (*Figure 37*) is that DOS EMS S1 measured more yellowfin tuna and skipjack tuna and less bigeye tuna than oversampling EU and oversampling IOTC.

The comparisons yield 57% of good results between oversampling EU and DOS EMS S1 and between oversampling IOTC and DOS EMS S1 for proportion of yellowfin tuna by commercial size category, with significant differences between the two methods for three of the seven fish tanks (Tank 5, Tank 6 and Tank 8) (*Table 48*). The general trend that is shown on the graphs (*Figure 38*) is that DOS EMS S1 measured more of the large (+10) yellowfin tuna and less of the small (-10) yellowfin tuna than oversampling EU and oversampling IOTC.

The comparisons yield 83.3% of good results between oversampling EU and DOS EMS S1 and between oversampling IOTC and DOS EMS S1 for proportion of bigeye tuna by commercial size category, with significant differences between the two methods for one of the six fish tanks (Tank 6) (*Table 49*). The general trend that is shown on the graphs (*Figure 39*) is that DOS EMS S1 measured more of the large (+10) bigeye tuna and less of the small (-10) bigeye tuna than oversampling EU and oversampling IOTC.

Comparison between Oversampling EU and Regular sampling EU and between Oversampling IOTC and Regular sampling IOTC

The comparisons yield 57% of good results between oversampling EU and regular sampling EU and between oversampling IOTC and regular sampling IOTC for proportion of tuna species, with significant differences between the methods for three of the seven fish tanks (Tank 4, Tank 5 and Tank 7) (*Table 47*). The general trend that is shown on the graphs (*Figure 37*) is that both regular sampling EU and regular sampling IOTC measured more yellowfin tuna and bigeye tuna and less skipjack tuna than oversampling EU and oversampling IOTC.

The comparisons did not yield good results between oversampling EU and regular sampling EU and between oversampling IOTC and regular sampling IOTC for proportion of yellowfin tuna by commercial size category, with most of them showing significant differences between the two methods (Tank 3, Tank 4, Tank 5, Tank 6 and Tank 8) (*Table 48*). The general trend that is shown on the graphs (*Figure 38*) is that both regular sampling EU and regular sampling IOTC measured more of the small (-10) yellowfin tuna and less of the large (+10) yellowfin tuna than oversampling EU and oversampling IOTC.

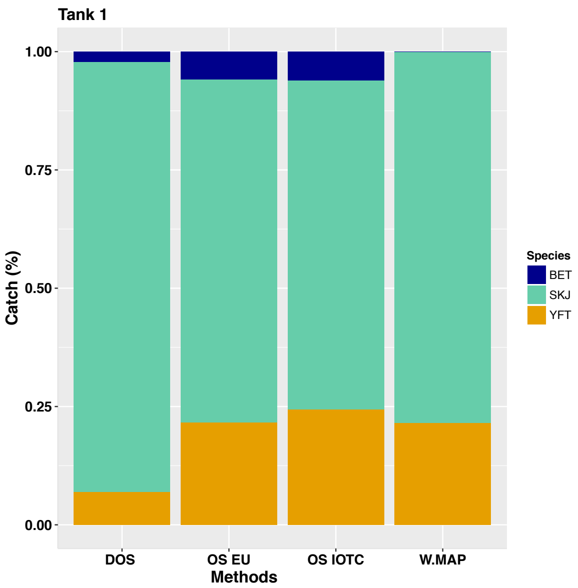
The comparisons yield 50% of good results between oversampling EU and regular sampling EU for proportion of bigeye tuna by commercial size category, with significant differences between the two methods for three of the six fish tanks (Tank 4, Tank 7 and Tank 8) and 66.7% of good results between oversampling IOTC and regular sampling IOTC, with significant differences between the two methods for two of the six fish tanks (Tank 7 and Tank 8) *(Table 49*). The general trend that is shown on the graphs (*Figure 39*) is that both regular sampling EU and regular sampling IOTC measured more of the small (-10) bigeye tuna and less of the large (+10) bigeye tuna than oversampling EU and oversampling IOTC.

Comparison between Oversampling EU and Oversampling IOTC with Well-map

The comparisons did not yield good results between oversampling EU and well-map and between oversampling IOTC and well-map for proportion of tuna species, with most of them showing significant differences between the two methods (Tank 2, Tank 3 Tank 4, Tank 6 and Tank 8) (*Table 47*). The general trend that is shown on the graphs (*Figure 37*) is that well-map measured more skipjack and less yellowfin tuna than oversampling EU and oversampling IOTC, and more or less the same amount of bigeye as oversampling EU and oversampling IOTC.

The comparisons did not yield good results between oversampling EU and well-map and between oversampling IOTC and well-map for proportion of yellowfin tuna by commercial size category, with significant differences between the two methods for five of the eight fish tanks (Tank 2, Tank 3, Tank 5, Tank 6 and Tank 8) (*Table 48*). The general trend that is shown on the graphs (*Figure 38*) is that well-map measured more of the small (-10) yellowfin tuna and less of the large (+10) yellowfin tuna than oversampling EU and oversampling IOTC.

The comparisons did not yield good results between oversampling EU and well-map and between oversampling IOTC and well-map for proportion of bigeye tuna by commercial size category, with significant differences between the two methods for three of the five fish tanks (Tank 3, Tank 5 and Tank 8) (*Table 49*). The general trend that is shown on the graphs (*Figure 39*) is that well-map measured more of the small (-10) bigeye tuna and less of the large (+10) bigeye tuna than oversampling EU and oversampling IOTC.


Tank 1
Catch (%)
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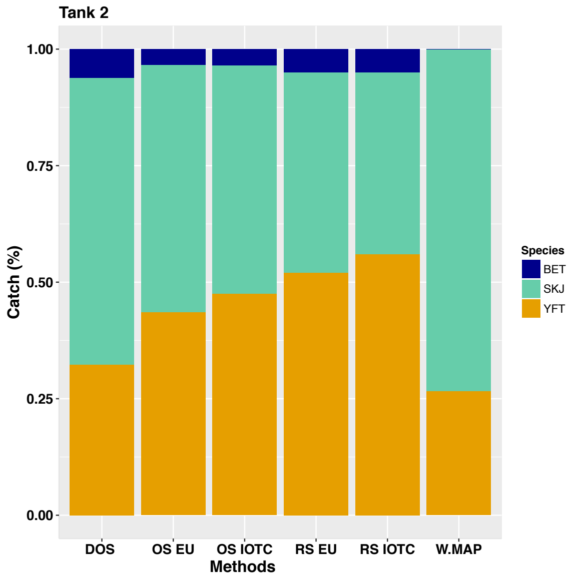
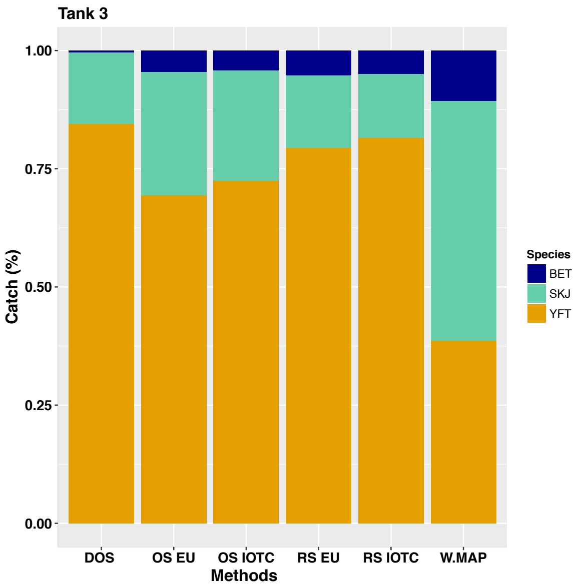
0.50
0.25
0.00
DOS
OS EU
OS IOTC
W.MAP
Methods
Species
BET
SKJ
YFT


Tank 2
Catch (%)
1.00
0.75
0.50
0.25
0.00
DOS
OS EU
OS IOTC
RS EU
RS IOTC
W.MAP
Methods
Species
BET
SKJ
YFT


Tank 3
Catch (%)
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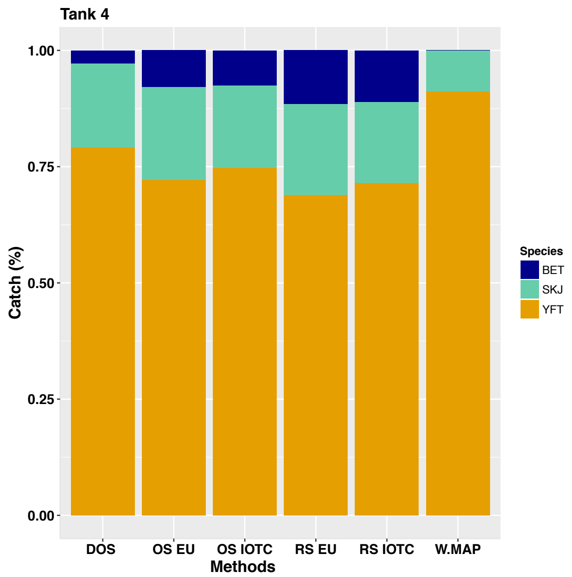
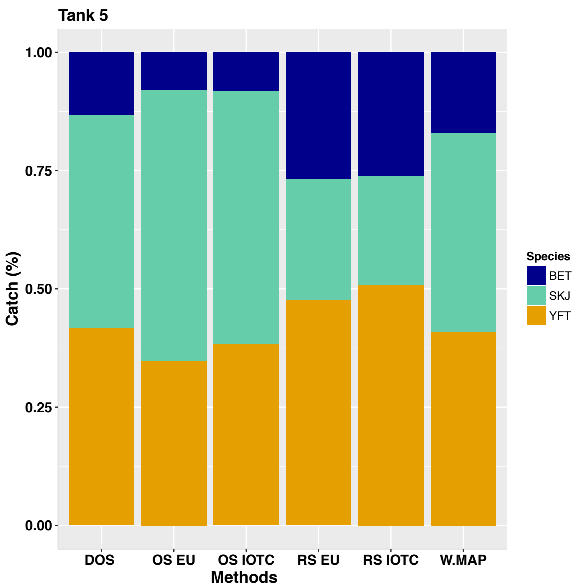
0.75
0.50
0.25
0.00
DOS
OS EU
OS IOTC
RS EU
RS IOTC
W.MAP
Methods
Species
BET
SKJ
YFT


Tank 4
Catch (%)
1.00
0.75
0.50
0.25
0.00
DOS
OS EU
OS IOTC
RS EU
RS IOTC
W.MAP
Methods
Species
BET
SKJ
YFT


Tank 5
Catch (%)
1.00
0.75
0.50
0.25
0.00
DOS
OS EU
OS IOTC
RS EU
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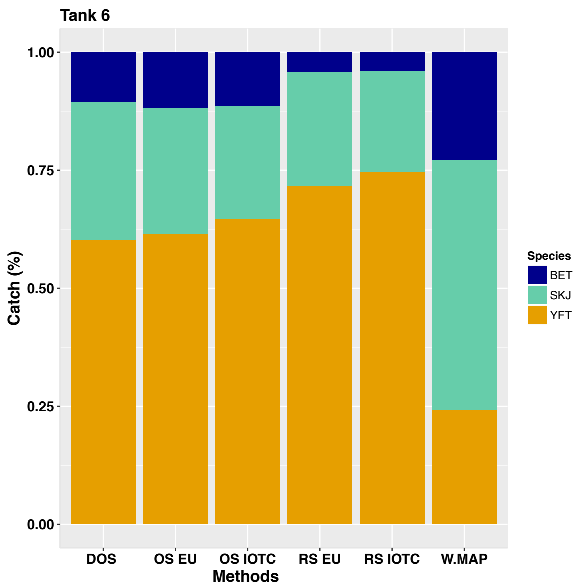
Species
BET
SKJ
YFT


Tank 6
Catch (%)
1.00
0.75
0.50
0.25
0.00
DOS
OS EU
OS IOTC
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Species
BET
SKJ
YFT

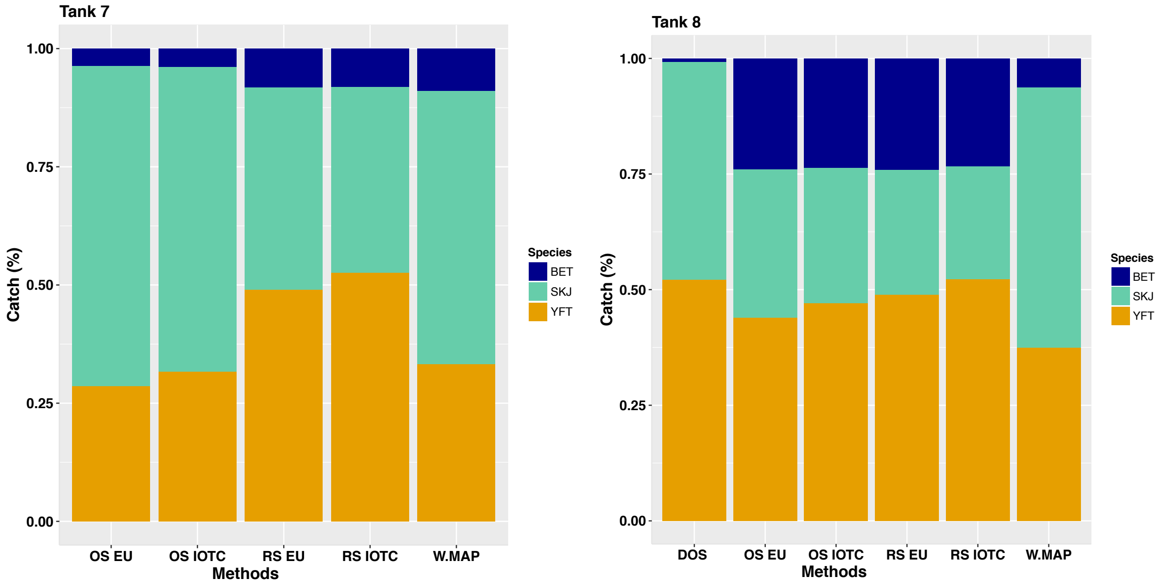


Figure 37: Proportion of tuna by species in the catch estimated by each method (DOS EMS S1 (DOS), Oversampling EU (OS EU), Oversampling IOTC (OS IOTC), Regular sampling EU (RS EU), Regular sampling IOTC (RS IOTC) and Well-map (W.MAP)) for each sampled fish tank (1 to 8).

Table 47: Results of chi-square test for proportion of tuna by species in the catch estimated by each method (DOS EMS S1 (DOS), Oversampling EU (OS EU), Oversampling IOTC (OS IOTC), Regular sampling EU (RS EU), Regular sampling IOTC (RS IOTC) and Well-map (W.MAP)) for each fish tank (1 to 8). Levels of significance were *p < 0.05, **p < 0.01 and ***p < 0.001). Yellow boxes indicate no data available for analysis.

Tank 1	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU	5.973*					
OS IOTC	7.411*					
RS EU						
RS IOTC						
W.MAP	5.576*	3.953	4.416			

Tank 2	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU	3.532					
OS IOTC	5.578					
RS EU	8.471*	2.120				
RS IOTC	11.624**		3.219			
W.MAP	8.137*	11.623**	14.856***	21.498***	25.353***	

Tank 3	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU	4.377					
OS IOTC	3.203					
RS EU	2.225	1.734				
RS IOTC	2.09		2.420			
W.MAP	26.802***	13.775***	16.29***	23.273***	25.463***	

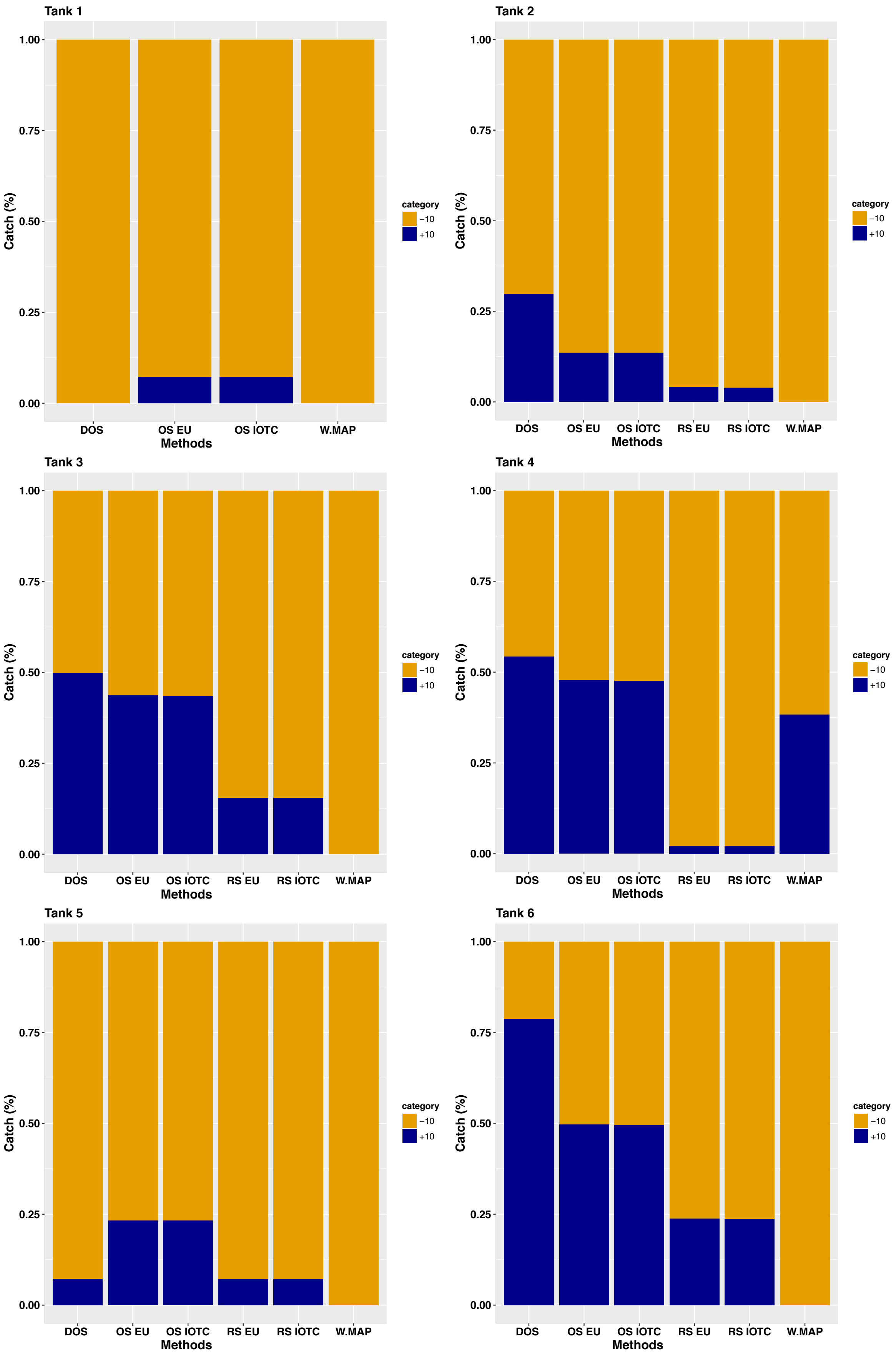
Tank 4	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU	2.073					
OS IOTC	1.650					
RS EU	3.896	16.998***				
RS IOTC	3.387		18.558***			
W.MAP	5.363*	11.438***	9.589**	13.661***	11.958***	

Tank 5	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU	3.253					
OS IOTC	1.932					
RS EU	10.277**	23.354***				
RS IOTC	11.594**		20.622***			
W.MAP	0.536	5.478	3.959	6.407*	7.781*	

Tank 6	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU	0.151					
OS IOTC	0.522					
RS EU	2.842	3.179				
RS IOTC	3.680		2.944			
W.MAP	18.145***	21.379***	24.385***	31.578***	34.208***	

Tank 7	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU						
OS IOTC						
RS EU		0.006**				
RS IOTC			0.006**			
W.MAP		2.519	1.735	4.105	5.934	

Tank 8	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU	18.67***					
OS IOTC	19.006***					
RS EU	19.554***	0.586				
RS IOTC	19.998***		0.554			
W.MAP	5.234	12.89**	14.355***	14.806***	16.158***	



Tank 1
Catch (%)
1.00
0.75
0.50
0.25
0.00
DOS
OS EU
OS IOTC
W.MAP
Methods
category
−10
+10
Tank 2
Catch (%)
DOS
OS EU
OS IOTC
RS EU
RS IOTC
W.MAP
Methods
category
−10
+10
Tank 3
Catch (%)
DOS
OS EU
OS IOTC
RS EU
RS IOTC
W.MAP
Methods
category
−10
+10
Tank 4
Catch (%)
DOS
OS EU
OS IOTC
RS EU
RS IOTC
W.MAP
Methods
category
−10
+10
Tank 5
Catch (%)
DOS
OS EU
OS IOTC
RS EU
RS IOTC
W.MAP
Methods
category
−10
+10
Tank 6
Catch (%)
DOS
OS EU
OS IOTC
RS EU
RS IOTC
W.MAP
Methods
category
−10
+10

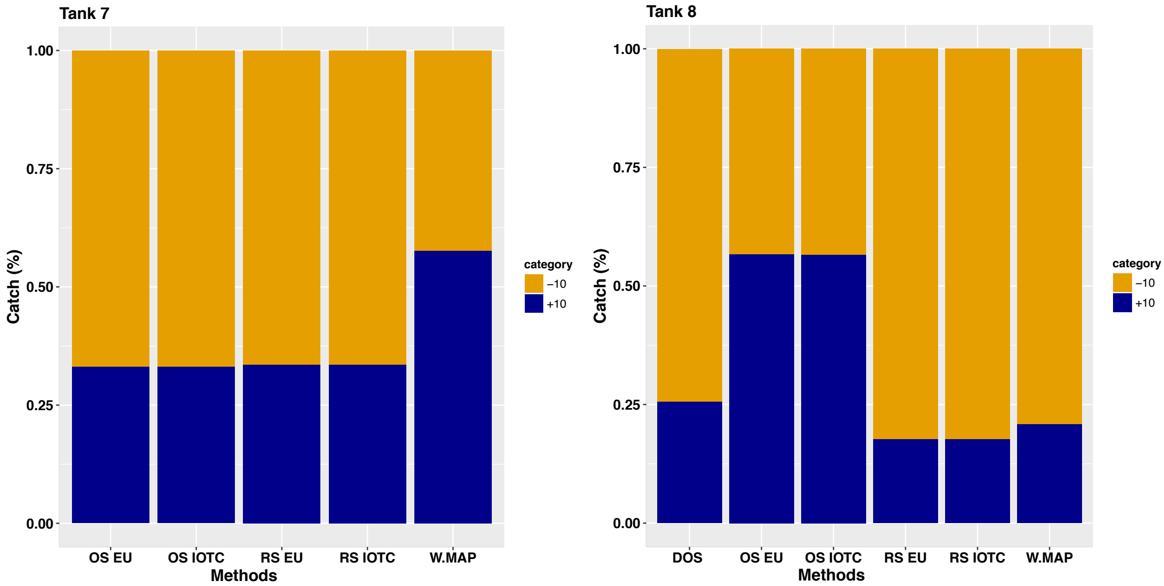


Figure 38: Proportion of yellowfin tuna (YFT) by commercial size category in the catch estimated by each method (DOS EMS S1 (DOS), Oversampling EU (OS EU), Oversampling IOTC (OS IOTC), Regular sampling EU (RS EU), Regular sampling IOTC (RS IOTC) and Well-map (W.MAP)) for each sampled fish tank (1to 8).

Table 48: Results of chi-square test for proportion of yellowfin tuna (YFT) by commercial size category in the catch estimated by each method (DOS EMS S1 (DOS), Oversampling EU (OS EU), Oversampling IOTC (OS IOTC), Regular sampling EU (RS EU), Regular sampling IOTC (RS IOTC) and Well-map (W.MAP)) for each sampled fish tank (1to 8). Levels of significance were *p < 0.05, **p < 0.01 and ***p < 0.001). Yellow boxes indicate no data available for analysis. Grey boxes indicate no analysis performed between two variables.

Tank 1	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU	0.243					
OS IOTC	0.243					
RS EU						
RS IOTC						
W.MAP		1.042	1.042			

Tank 2	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU	3.362					
OS IOTC	3.365					
RS EU	10.809***	2.738				
RS IOTC	11.049***		2.882			
W.MAP	10.02**	4.191*	4.190*	1.211	1.152	

Tank 3	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU	0.353					
OS IOTC	0.370					
RS EU	12.559***	9.285**				
RS IOTC	12.559***		9.285**			
W.MAP	20.63***	17.425***	17.335***	4.984*	4.984*	

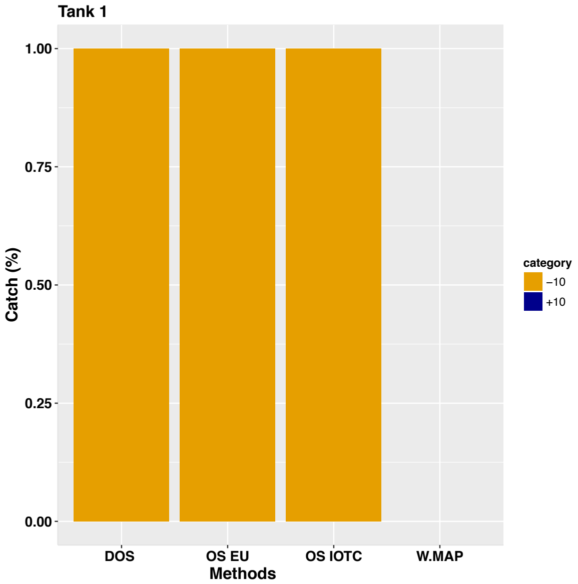
Tank 4	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU	0.468					
OS IOTC	0.498					
RS EU	24.2***	19.55***				
RS IOTC	24.187***		19.39***			
W.MAP	3.318	1.157	1.105	14.562***	14.553***	

Tank 5	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU	3.746*					
OS IOTC	3.746*					
RS EU	0.001	4.277*				
RS IOTC	0.001		4.277*			
W.MAP	2.741	9.435***	9.435***	2.669	2.669	

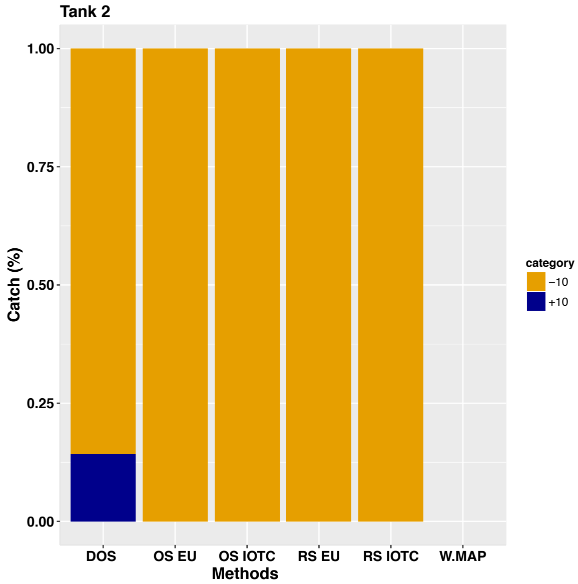
Tank 6	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU	8.072**					
OS IOTC	8.161**					
RS EU	25.749***	6.882**				
RS IOTC	25.869***		6.849*			
W.MAP	29.925***	13.477***	13.384***	4.919*	4.883*	

Tank 7	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU						
OS IOTC						
RS EU		0.001				
RS IOTC			0.001			
W.MAP		2.790	2.790	3.693*	3.693*	

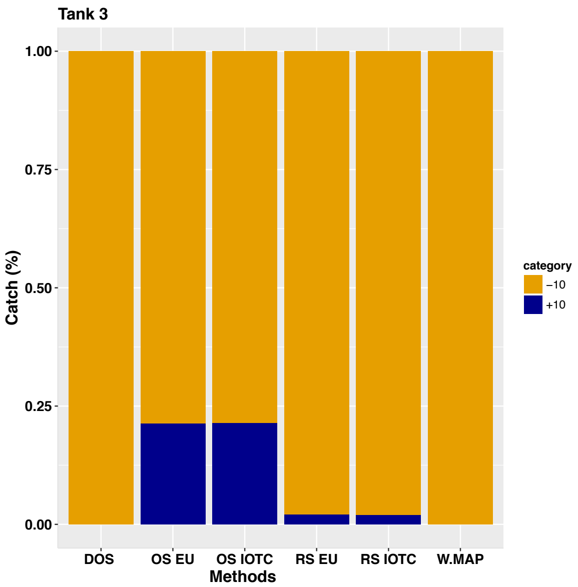
Tank 8	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU	7.805**					
OS IOTC	7.749**					
RS EU	0.659	12.111***				
RS IOTC	0.669		12.101***			
W.MAP	0.188	8.019**	7.97**	0.088	0.091	



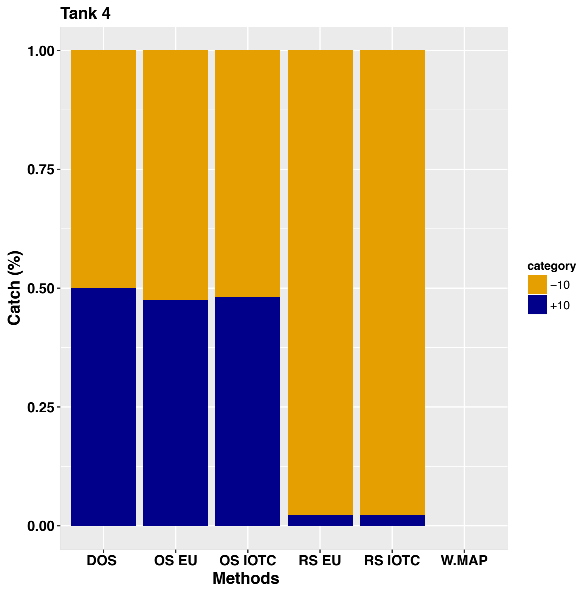
Tank 1
Catch (%)
1.00
0.75
0.50
0.25
0.00
DOS
OS EU
OS IOTC
W.MAP
Methods
category
−10
+10



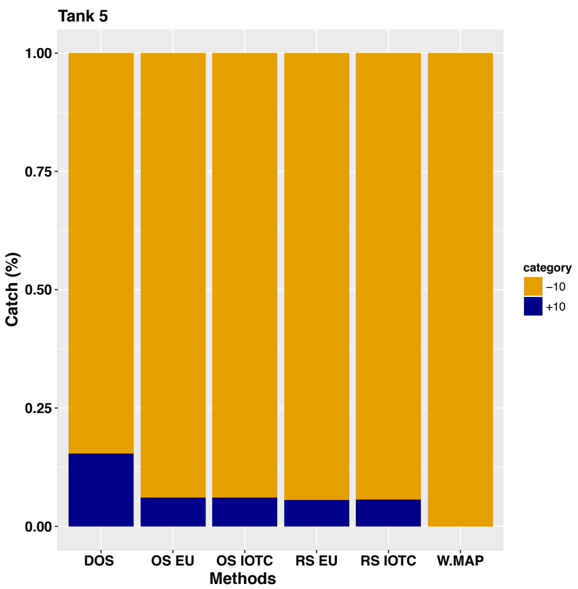
Tank 2
Catch (%)
1.00
0.75
0.50
0.25
0.00
DOS
OS EU
OS IOTC
RS EU
RS IOTC
W.MAP
Methods
category
−10
+10



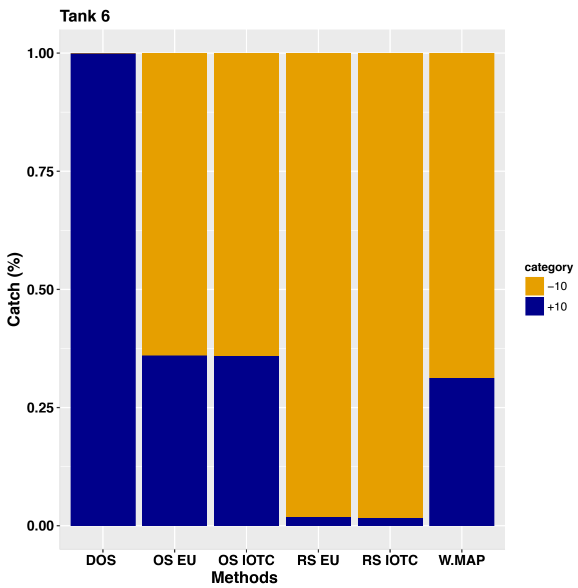
Tank 3
Catch (%)
1.00
0.75
0.50
0.25
0.00
DOS
OS EU
OS IOTC
RS EU
RS IOTC
W.MAP
Methods
category
−10
+10



Tank 4
Catch (%)
1.00
0.75
0.50
0.25
0.00
DOS
OS EU
OS IOTC
RS EU
RS IOTC
W.MAP
Methods
category
−10
+10



Tank 5
Catch (%)
1.00
0.75
0.50
0.25
0.00
DOS
OS EU
OS IOTC
RS EU
RS IOTC
W.MAP
Methods
category
−10
+10



Tank 6
Catch (%)
1.00
0.75
0.50
0.25
0.00
DOS
OS EU
OS IOTC
RS EU
RS IOTC
W.MAP
Methods
category
−10
+10

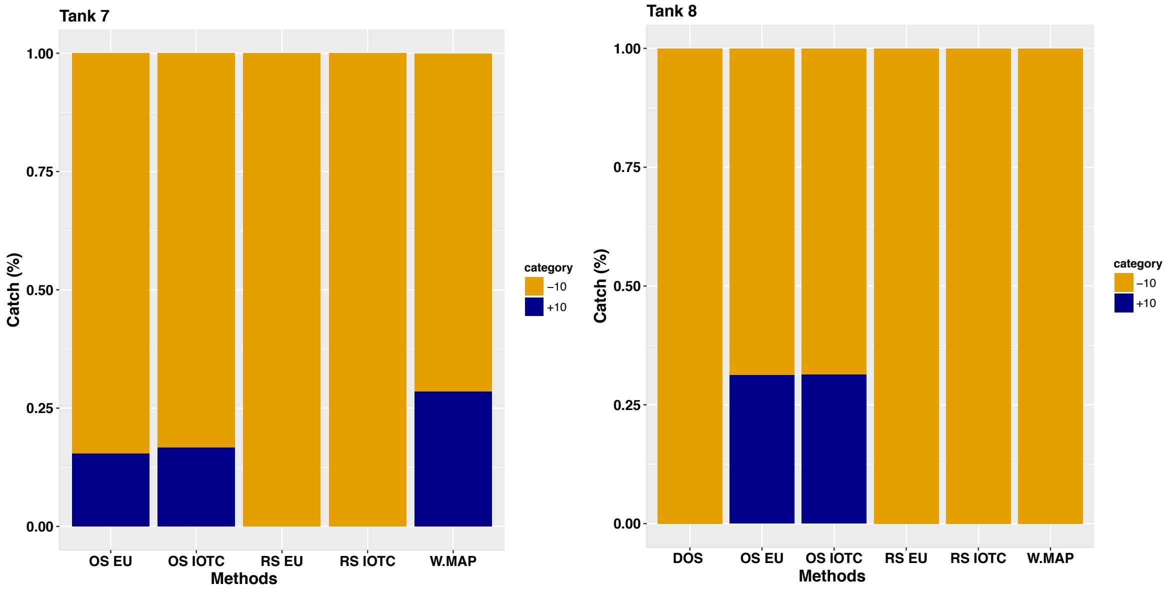


Figure 39: Proportion of bigeye tuna (BET) by commercial size category in the catch estimated by each method (DOS EMS S1 (DOS), Oversampling EU (OS EU), Oversampling IOTC (OS IOTC), Regular sampling EU (RS EU), Regular sampling IOTC (RS IOTC) and Well-map (W.MAP)) for each sampled fish tank (1to 8).

Table 49: Results of chi-square test for proportion of bigeye tuna (BET) by commercial size category in the catch estimated by each method (DOS EMS S1 (DOS), Oversampling EU (OS EU), Oversampling IOTC (OS IOTC), Regular sampling EU (RS EU), Regular sampling IOTC (RS IOTC) and Well-map (W.MAP)) for each sampled fish tank (2 to 8). Levels of significance were *p < 0.05, **p < 0.01 and ***p < 0.001). Yellow boxes indicate no data available for analysis. Grey boxes indicate no analysis performed between two variables.

Tank 2	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU	0.613					
OS IOTC	0.568					
RS EU	0.749					
RS IOTC	0.689					
W.MAP						

Tank 3	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU	0.053					
OS IOTC	0.054					
RS EU	0.004	0.575				
RS IOTC	0.004		0.534			
W.MAP		1.812***	1.815***	0.172***	0.163	

Tank 4	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU	0.004					
OS IOTC	0.002					
RS EU	2.557	2.969***				
RS IOTC	2.357		2.744			
W.MAP						

Tank 5	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU	0.380					
OS IOTC	0.355					
RS EU	1.046	0.003				
RS IOTC	0.963		0.002			
W.MAP	2.485	0.937***	0.934***	0.871	0.889	

Tank 6	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU	7.116*					
OS IOTC	6.988**					
RS EU	9.401***	1.188				
RS IOTC	9.233***		1.105			
W.MAP	9.224**	0.064	0.057	0.993	0.935	

Tank 7	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU						
OS IOTC						
RS EU		1.046***				
RS IOTC			1.043***			
W.MAP		0.176	0.133	2.180	2.014	

Tank 8	DOS	OS EU	OS IOTC	RS EU	RS IOTC	W.MAP
DOS						
OS EU	0.226					
OS IOTC	0.227					
RS EU		6.47*				
RS IOTC			5.926**			
W.MAP		1.711*	1.711*			

Comparison between Unloading and SFA EMS

The comparisons did not yield good results between unloading and SFA EMS for proportion of tuna species, with all of them showing significant differences between the two methods (Trip 1, Trip 2, Trip 3, Trip 4, Trip 5, Trip 6, Trip 7 and Trip 9) (*Table 50*). The general trend that is shown on the graphs (*Figure 40*) is that SFA EMS measured less yellowfin tuna than unloading and more or less the same amount of bigeye tuna and skipjack tuna.

Comparison between Unloading and Logbook

The comparisons did not yield good results between unloading and logbook for proportion of tuna species, with all of them showing significant differences between the two methods (Trip 1 to 10) (*Table 50*). The general trend that is shown on the graphs (*Figure 40*) is that logbook measured more bigeye tuna and skipjack tuna and less yellowfin tuna than unloading.

The comparisons did not yield good results between unloading and logbook for proportion of yellowfin tuna by commercial size category, with most of them showing significant differences between the two methods (Trip 1, Trip 2, Trip 3, Trip 4, Trip 5, Trip 6, Trip 7, Trip 9 and Trip 10) (*Table 51*). The general trend that is shown on the graphs (*Figure 41*) is that logbook measured more of the small (-10) yellowfin tuna and less of the large (+10) yellowfin tuna than unloading.

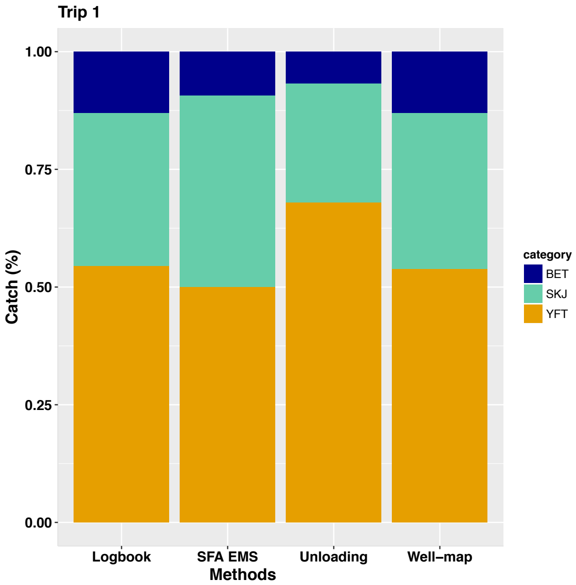
The comparisons did not yield good results between unloading and logbook for proportion of bigeye tuna by commercial size category, with most of them showing significant differences between the two methods (Trip 1, Trip 2, Trip 3, Trip 4, Trip 5, Trip 7, Trip 8, Trip 9 and Trip 10) (*Table 52*). The general trend that is shown on the graphs (*Figure 42*) is that logbook measured more of the small (-10) bigeye tuna and less of the large (+10) bigeye tuna than unloading.

Comparison between Unloading and Well-map

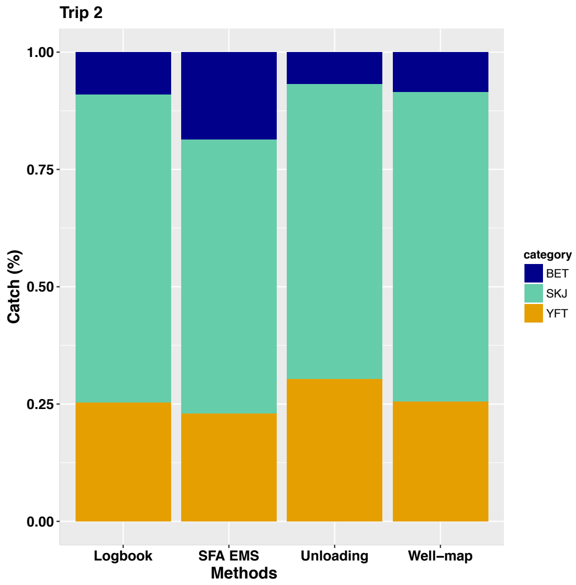
The comparisons did not yield good results between unloading and well-map for proportion of tuna species, with all of them showing significant differences between the two methods (Trip 1 to 10) (*Table 50*). The general trend that is shown on the graphs (*Figure 40*) is that well-map measured more bigeye tuna and skipjack tuna and less yellowfin tuna than unloading.

The comparisons did not yield good results between unloading and well-map for proportion of yellowfin tuna by commercial size category, with all of them showing significant differences between the two methods (Trip 1 to 10) (*Table 51*). The general trend that is shown on the graphs (*Figure 41*) is that well-map measured more of the small (-10) yellowfin tuna and less of the large (+10) yellowfin tuna than unloading.

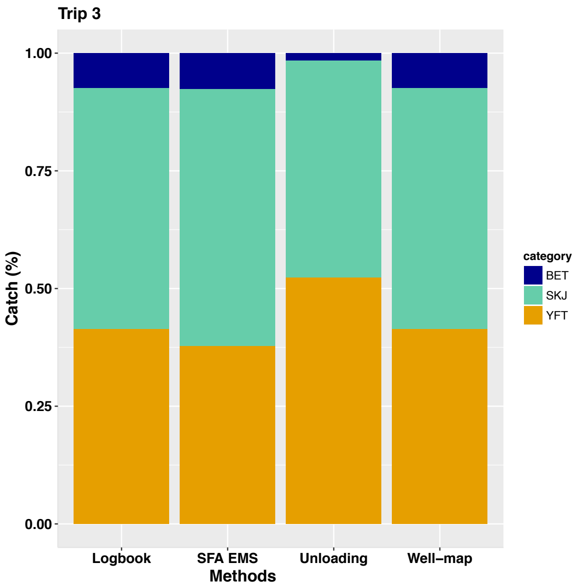
The comparisons did not yield good results between unloading and well-map for proportion of bigeye tuna by commercial size category, with all of them showing significant differences between the two methods (Trip 1 to 10) (*Table 52*). The general trend that is shown on the graphs (*Figure 42*) is that well-map measured more of the small (-10) bigeye tuna and less of the large (+10) bigeye tuna than unloading.



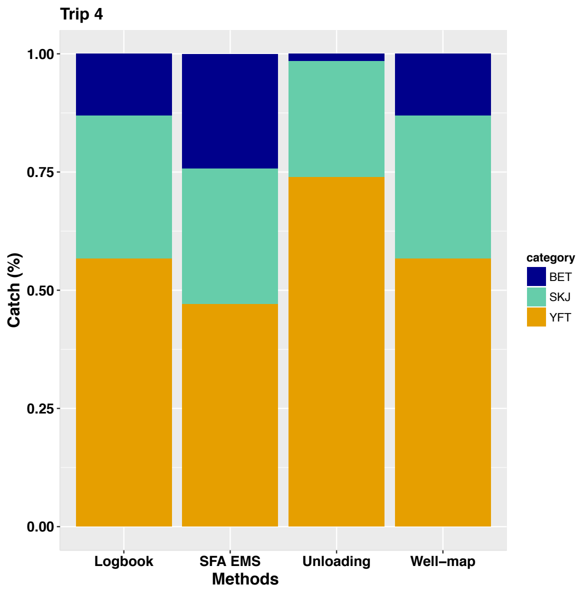
Trip 1
1.00
0.75
0.50
0.25
0.00
Catch (%)
Logbook
SFA EMS
Unloading
Well–map
Methods
category
BET
SKJ
YFT



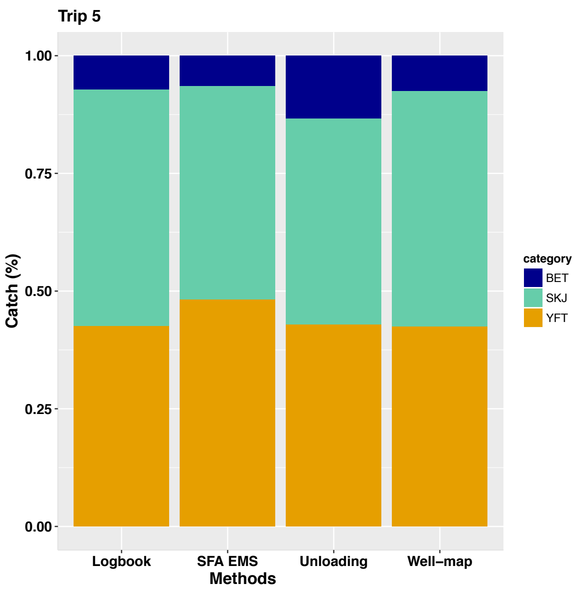
Trip 2
1.00
0.75
0.50
0.25
0.00
Catch (%)
Logbook
SFA EMS
Unloading
Well–map
Methods
category
BET
SKJ
YFT



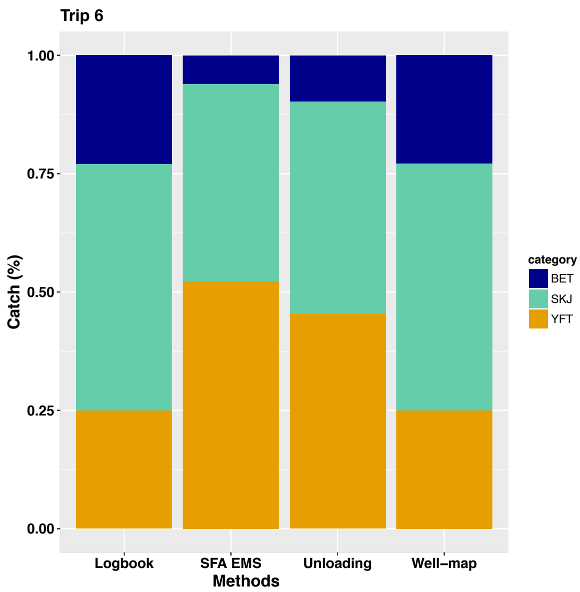
Trip 3
1.00
0.75
0.50
0.25
0.00
Catch (%)
Logbook
SFA EMS
Unloading
Well–map
Methods
category
BET
SKJ
YFT



Trip 4
1.00
0.75
0.50
0.25
0.00
Catch (%)
Logbook
SFA EMS
Unloading
Well–map
Methods
category
BET
SKJ
YFT



Trip 5
1.00
0.75
0.50
0.25
0.00
Catch (%)
Logbook
SFA EMS
Unloading
Well–map
Methods
category
BET
SKJ
YFT



Trip 6
1.00
0.75
0.50
0.25
0.00
Catch (%)
Logbook
SFA EMS
Unloading
Well–map
Methods
category
BET
SKJ
YFT

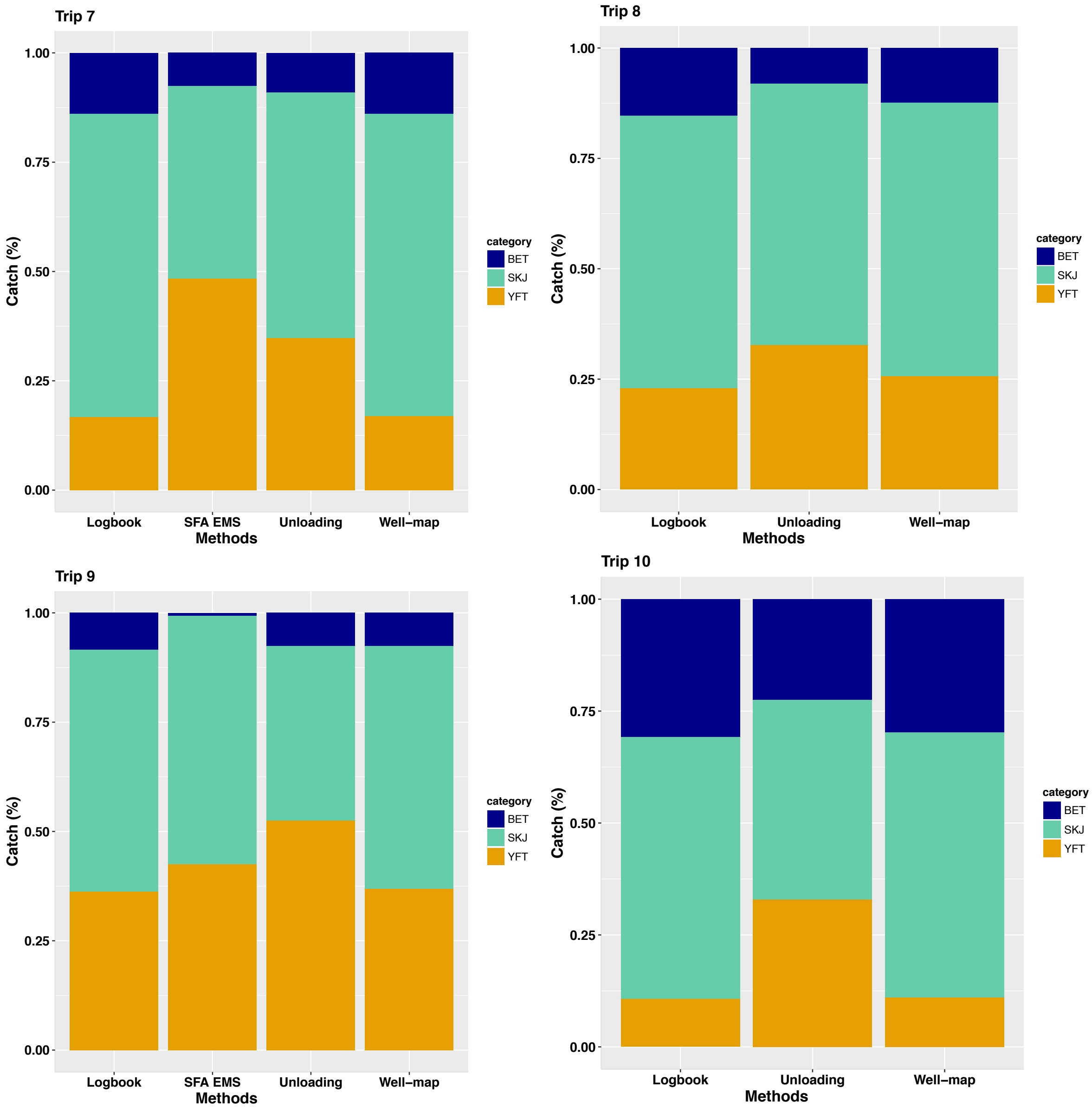


Figure 40: Proportion of tuna by species in the catch estimated by each method (Logbook, Unloading and Well-map) for each sampled fishing trip (1-10).

Table 50: Results of chi-square test for proportion of tuna by species in the catch estimated by each method (Logbook, Scientific Observer Programme (S. Observer) Unloading and Well-map) for each sampled fishing trip (1-10). Levels of significance were *p < 0.05, **p < 0.01 and ***p < 0.001). Yellow boxes indicate no data available for analysis.

Trip 1	Logbook	SFA EMS	Unloading	Well-map
Logbook				
SFA EMS	14.36***			
Unloading	40.545***	60.22***		
Well-map	0.069	12.896**	43.051***	

Trip 2	Logbook	SFA EMS	Unloading	Well-map
Logbook				
SFA EMS	50.849***			
Unloading	12.305**	93.647***		
Well-map	0.285	54.531***	9.486**	

Trip 3	Logbook	SFA EMS	Unloading	Well-map
Logbook				
SFA EMS	3.271			
Unloading	82.455***	98.679***		
Well-map	0	3.271	82.455***	

Trip 4	Logbook	SFA EMS	Unloading	Well-map
Logbook				
SFA EMS	39.072***			
Unloading	122.34***	252.46***		
Well-map	0	39.072***	122.34***	

Trip 5	Logbook	SFA EMS	Unloading	Well-map
Logbook				
SFA EMS	5.091			
Unloading	18.266***	21.759***		
Well-map	0.064	5.288	16.351***	

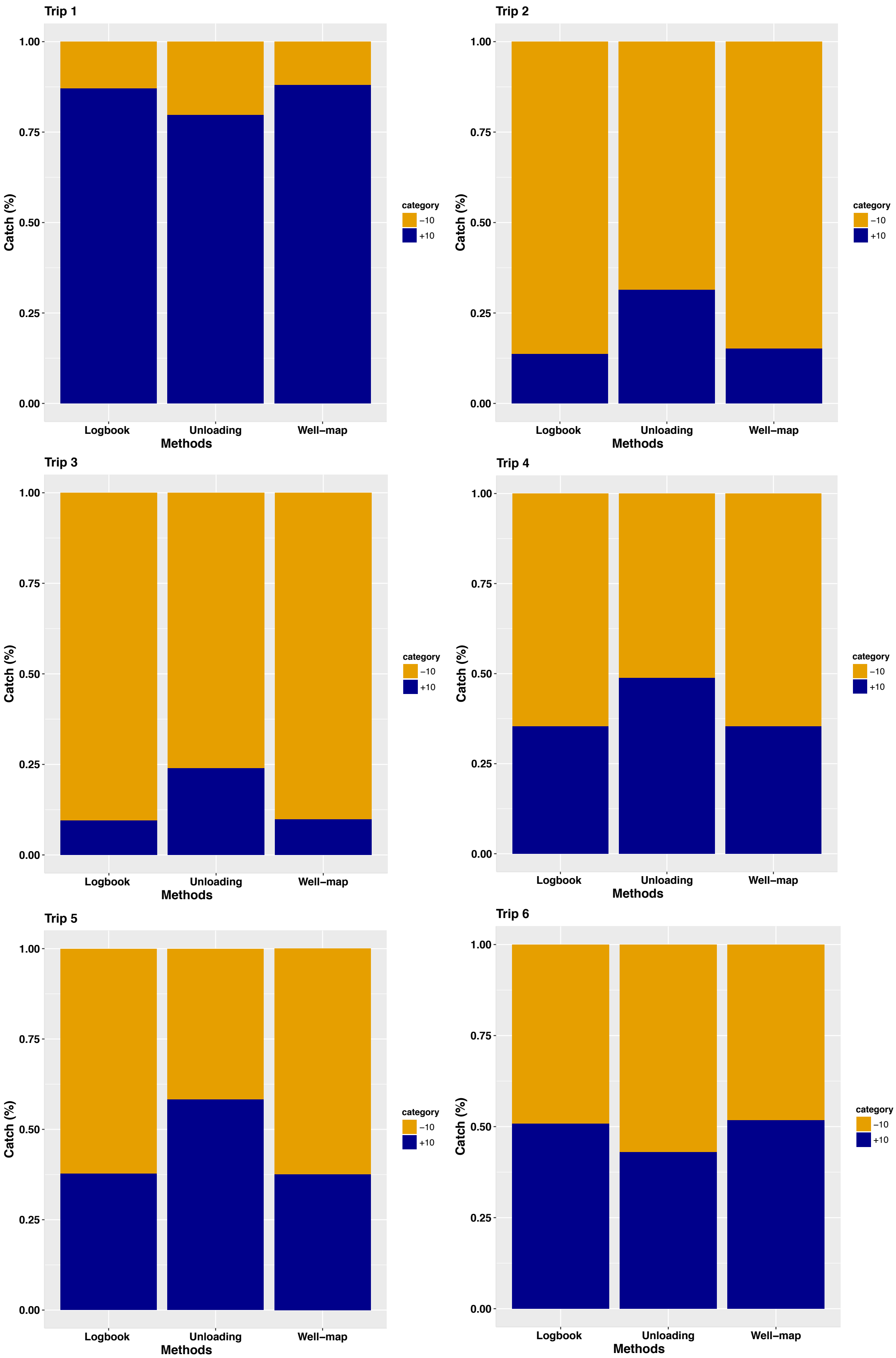
Trip 6	Logbook	SFA EMS	Unloading	Well-map
Logbook				
SFA EMS	285.01***			
Unloading	188.6***	21.096***		
Well-map	0.006	288.46***	191.17***	

Trip 7	Logbook	SFA EMS	Unloading	Well-map
Logbook				
SFA EMS	159.18***			
Unloading	66.246***	27.573***		
Well-map	0.022	163.88***	67.682***	

Trip 8	Logbook	SFA EMS	Unloading	Well-map
Logbook				
SFA EMS				
Unloading	31.301***			
Well-map	3.706		14.078***	

Trip 9	Logbook	SFA EMS	Unloading	Well-map
Logbook				
SFA EMS	35.251***			
Unloading	26.687***	48.062***		
Well-map	0.232	30.848***	25.594***	

Trip 10	Logbook	SFA EMS	Unloading	Well-map
Logbook				
SFA EMS				
Unloading	102.38***			
Well-map	0.192		98.676***	


Trip 1
Trip 2
Trip 3
Trip 4
Trip 5
Trip 6
1.00
0.75
0.50
0.25
0.00
Catch (%)
Logbook
Unloading
Well–map
Methods
category
−10
+10

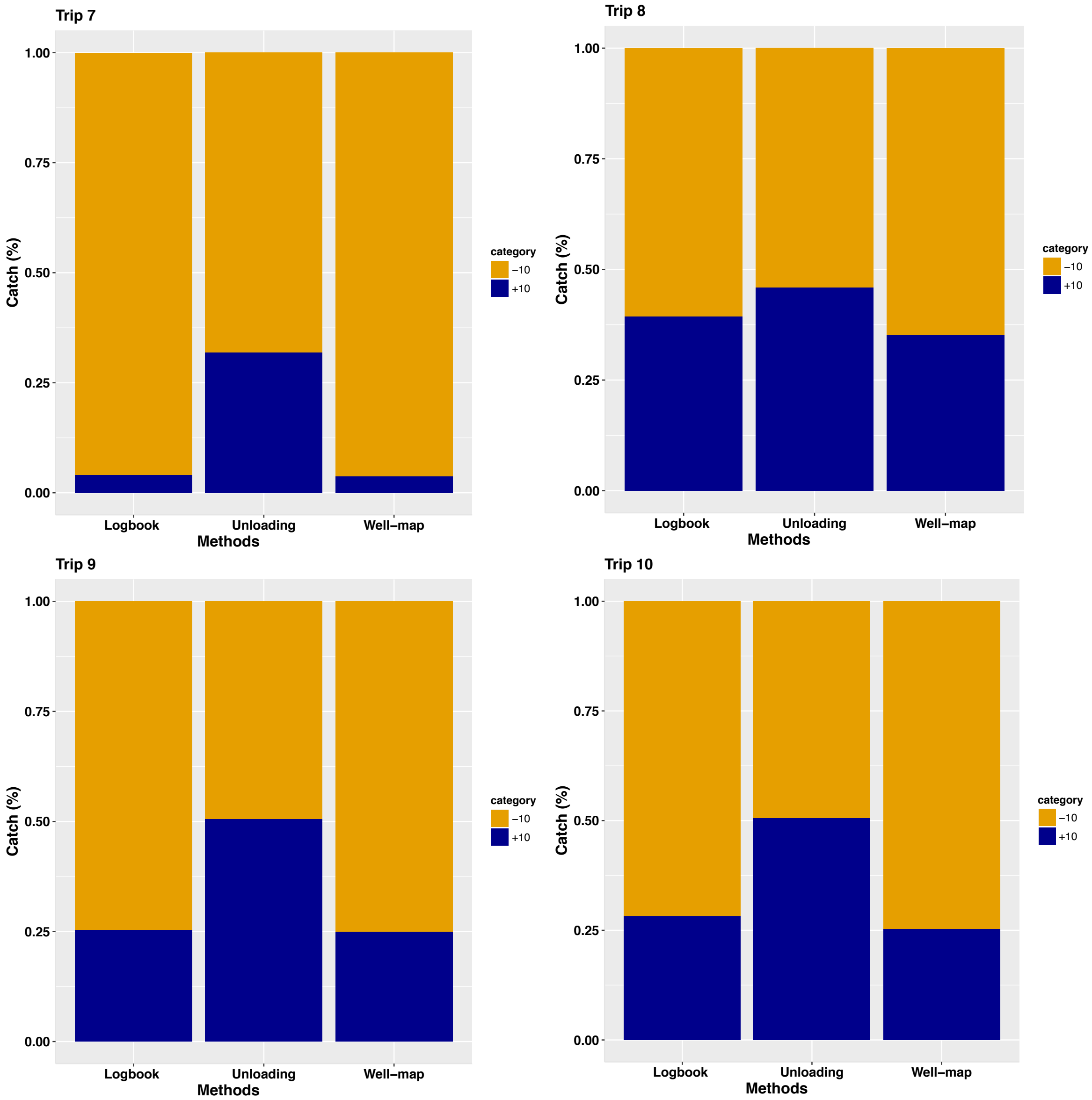


Figure 41:Proportion of yellowfin tuna (YFT) by commercial size category in the catch estimated by each method (Logbook, Unloading and Well-map) for each sampled fishing trip (1-10).

Table 51: Results of chi-square test for proportion of yellowfin tuna (YFT) by commercial size category in the catch estimated by each method (Logbook, Unloading and Well-map) for each sampled fishing trip (1-10). Levels of significance were *p < 0.05, **p < 0.01 and ***p < 0.001).

Trip 1	Logbook	Unloading	Well-map
Logbook			
Unloading	10.572***		
Well-map	0.184	13.509***	

Trip 2	Logbook	Unloading	Well-map
Logbook			
Unloading	35.961***		
Well-map	0.313	27.588***	

Trip 3	Logbook	Unloading	Well-map
Logbook			
Unloading	49.725***		
Well-map	0.038	47.198***	

Trip 4	Logbook	Unloading	Well-map
Logbook			
Unloading	24.368***		
Well-map	0	24.368***	

Trip 5	Logbook	Unloading	Well-map
Logbook			
Unloading	28.474***		
Well-map	0.004	29.209***	

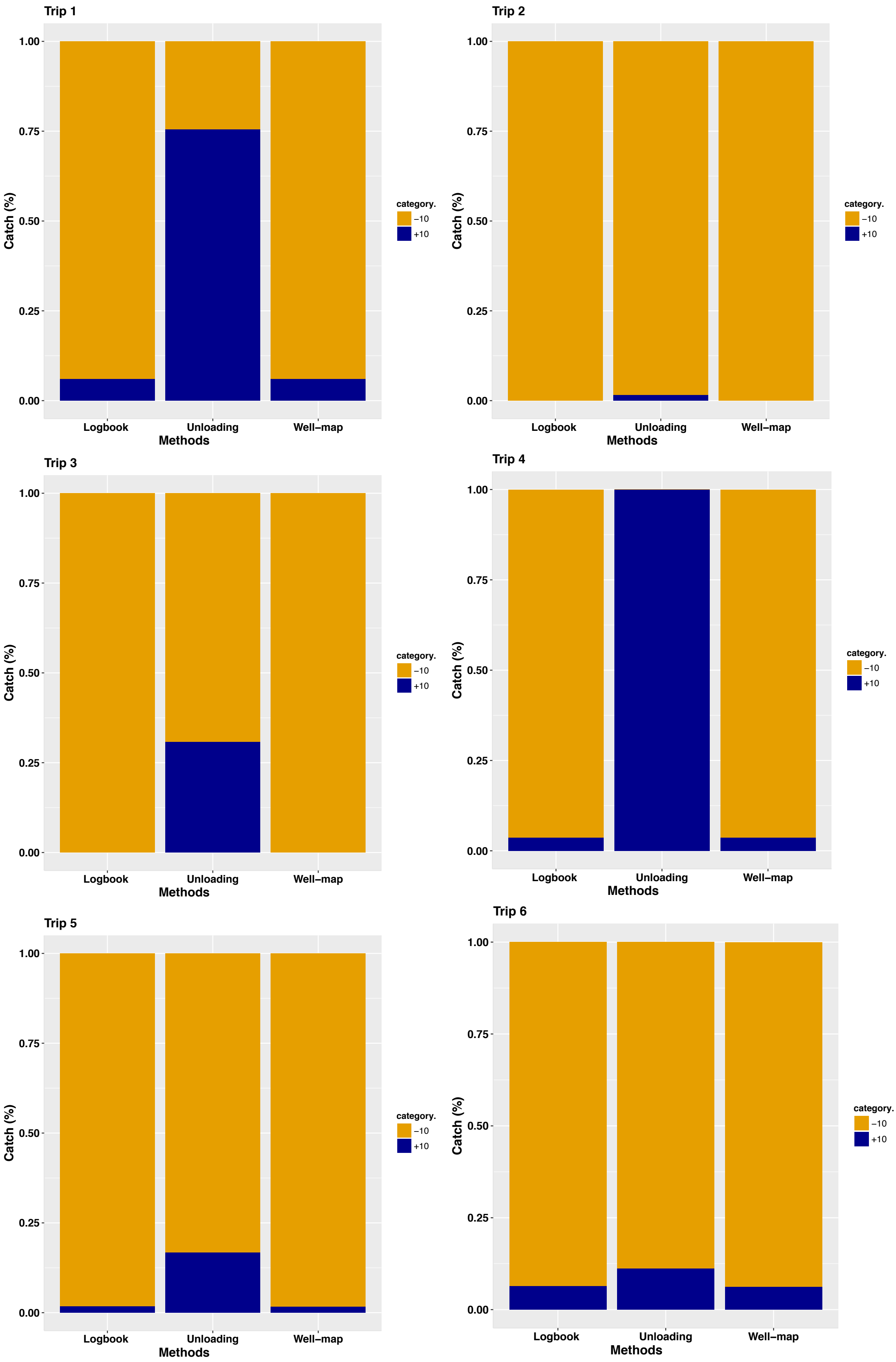
Trip 6	Logbook	Unloading	Well-map
Logbook			
Unloading	6.241*		
Well-map	0.074	8.044**	

Trip 7	Logbook	Unloading	Well-map
Logbook			
Unloading	36.541***		
Well-map	0.023	40.839***	

Trip 8	Logbook	Unloading	Well-map
Logbook			
Unloading	1.789		
Well-map	0.752	5.364*	

Trip 9	Logbook	Unloading	Well-map
Logbook			
Unloading	27.438***		
Well-map	0.008	28.717***	

Trip 10	Logbook	Unloading	Well-map
Logbook			
Unloading	11.738***		
Well-map	0.167	15.161***	


Trip 1
Trip 2
Trip 3
Trip 4
Trip 5
Trip 6
Catch (%)
1.00
0.75
0.50
0.25
0.00
Logbook
Unloading
Well–map
Methods
category.
–10
+10

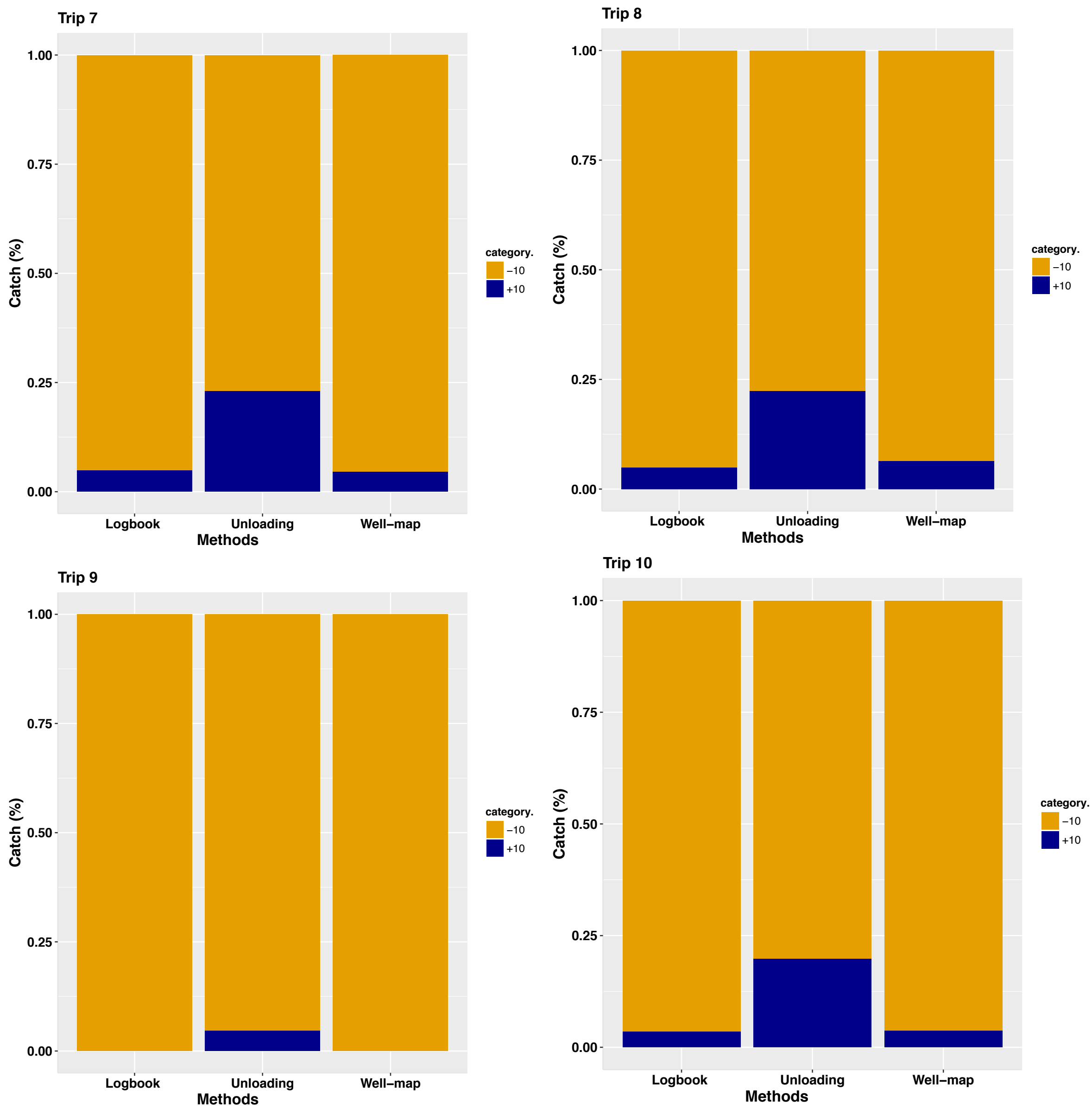


Figure 42:Proportion of bigeye tuna (BET) by commercial size category in the catch estimated by each method (Logbook, Unloading and Well-map) for each sampled fishing trip (1-10).

Table 52: Results of chi square test for proportion of bigeye tuna (BET) by commercial size category in the catch estimated by each method (Logbook, Unloading and Well-map) for each sampled fishing trip (1-10). Levels of significance were *p < 0.05, **p < 0.01 and ***p < 0.001). Grey boxes indicate no analysis performed between two variables.

Trip 1	Logbook	Unloading	Well-map
Logbook			
Unloading	154.66***		
Well-map	0	154.66***	

Trip 2	Logbook	Unloading	Well-map
Logbook			
Unloading	2.039***		
Well-map		1.71***	

Trip 3	Logbook	Unloading	Well-map
Logbook			
Unloading	35.266***		
Well-map		35.266***	

Trip 4	Logbook	Unloading	Well-map
Logbook			
Unloading	110.83***		
Well-map	0	110.83***	

Trip 5	Logbook	Unloading	Well-map
Logbook			
Unloading	7.876**		
Well-map	0.001	8.39**	

Trip 6	Logbook	Unloading	Well-map
Logbook			
Unloading	3.431		
Well-map	0.009	3.786*	

Trip 7	Logbook	Unloading	Well-map
Logbook			
Unloading	12.687***		
Well-map	0.019	14.338***	

Trip 8	Logbook	Unloading	Well-map
Logbook			
Unloading	12.695***		
Well-map	0.208	8.445**	

Trip 9	Logbook	Unloading	Well-map
Logbook			
Unloading	1.969***		
Well-map		1.779***	

Trip 10	Logbook	Unloading	Well-map
Logbook			
Unloading	26.392***		
Well-map	0.009	24.769***	

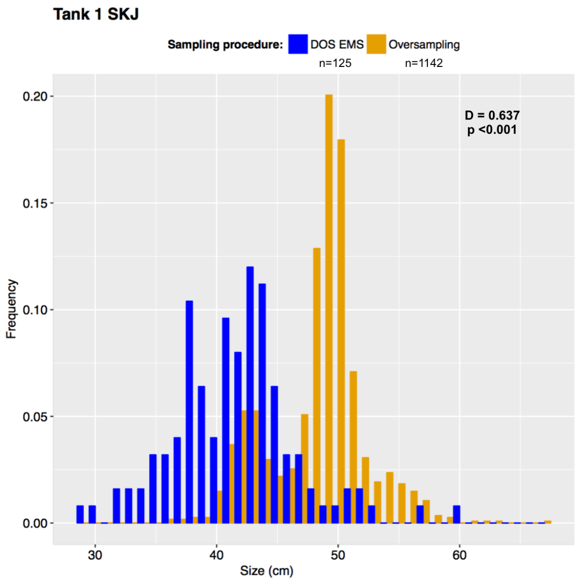
3.3 Comparison of Fish Size Distributions for Retained Tuna

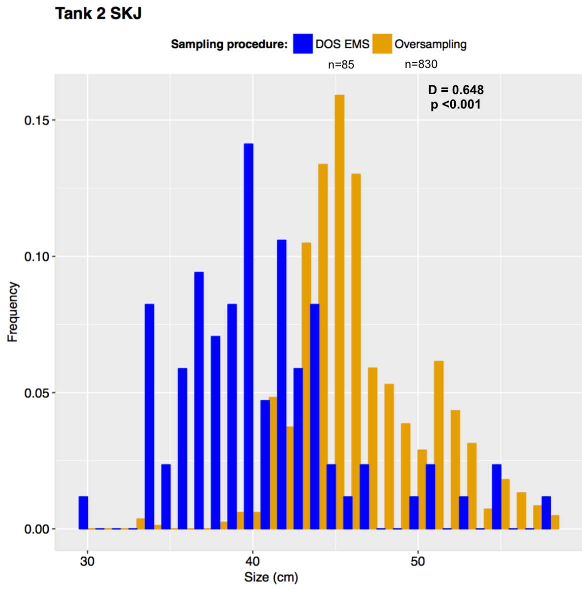
Comparison between Oversampling and DOS EMS S1

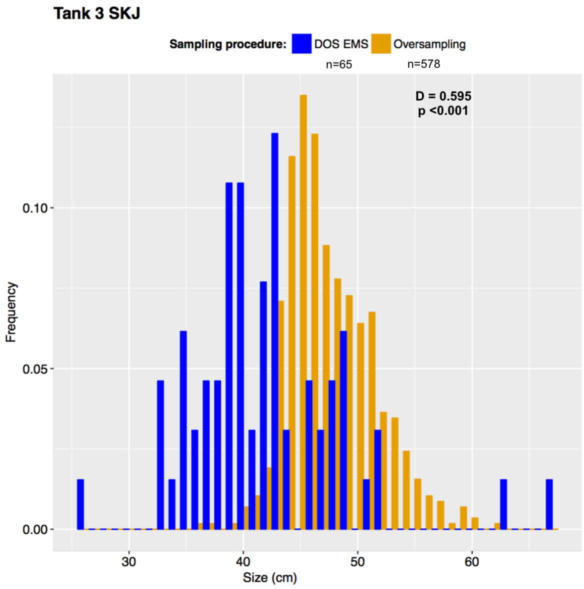
The comparisons did not yield good results between oversampling and DOS EMS S1 for fish size distribution of the catch of skipjack tuna, with most of them showing significant differences between the two methods (Tank 1, Tank 2, Tank 3, Tank 4, Tank 5 and Tank 6). The general trend that is shown on the graphs (*Figure 43*) is that DOS EMS S1 underestimate the size of skipjack tuna.

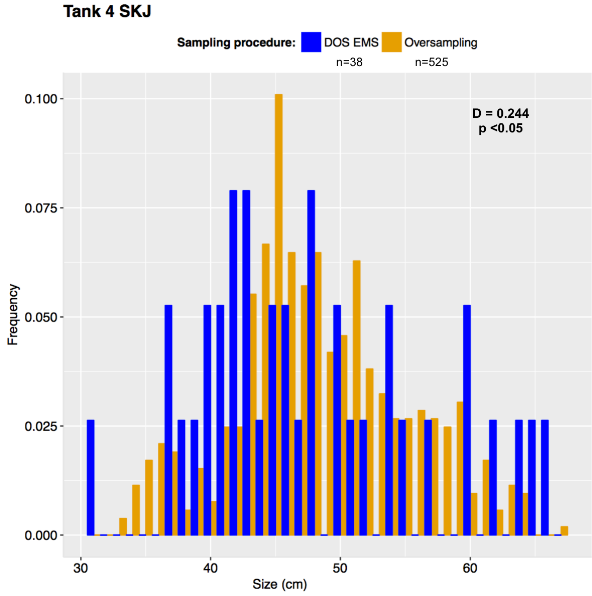
The comparisons did not yield good results between oversampling and DOS EMS S1 for fish size distribution of the catch of yellowfin tuna, with most of them showing significant differences between the two methods (Tank 1, Tank 2, Tank 4, Tank 5, Tank 6 and Tank 8). The general trend that is shown on the graphs (*Figure 44*) is that DOS EMS S1 underestimate the size of yellowfin tuna.

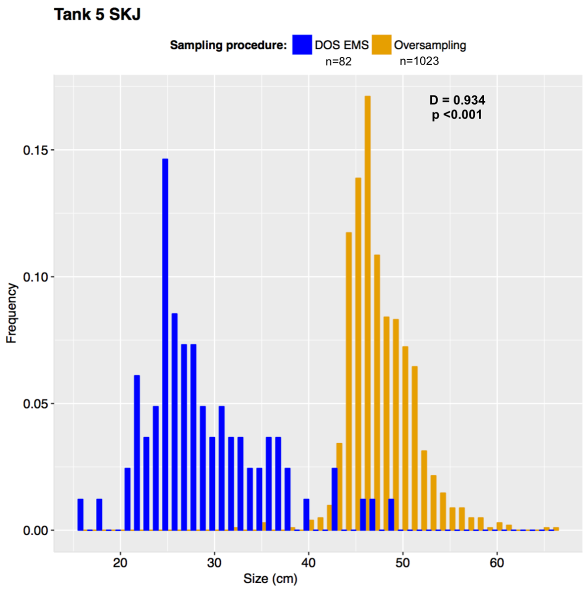
The comparisons between oversampling and DOS EMS S1 for fish size distribution of the catch of bigeye tuna, showed that there was significant difference between the two methods for one of the six fish tanks (Tank 5). It was not possible to see a clear trend on the graphs (*Figure 45*) because DOS EMS S1 sampled very few bigeye tuna and this did not permit for a reasonably good comparison between the two methods.

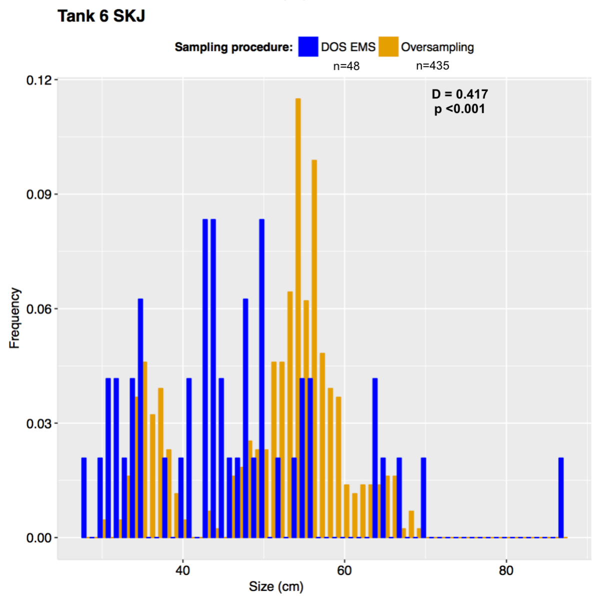

Tank 1 SKJ
Sampling procedure: DOS EMS Oversampling
n=125 n=1142
D = 0.637
p <0.001
Frequency
Size (cm)


Tank 2 SKJ
Sampling procedure: DOS EMS Oversampling
n=85 n=830
D = 0.648
p <0.001
Frequency
Size (cm)


Tank 3 SKJ
Sampling procedure: DOS EMS Oversampling
n=65 n=578
D = 0.595
p <0.001
Frequency
Size (cm)


Tank 4 SKJ
Sampling procedure: DOS EMS Oversampling
n=38 n=525
D = 0.244
p <0.05
Frequency
Size (cm)


Tank 5 SKJ
Sampling procedure: DOS EMS Oversampling
n=82 n=1023
D = 0.934
p <0.001
Frequency
Size (cm)


Tank 6 SKJ
Sampling procedure: DOS EMS Oversampling
n=48 n=435
D = 0.417
p <0.001
Frequency
Size (cm)

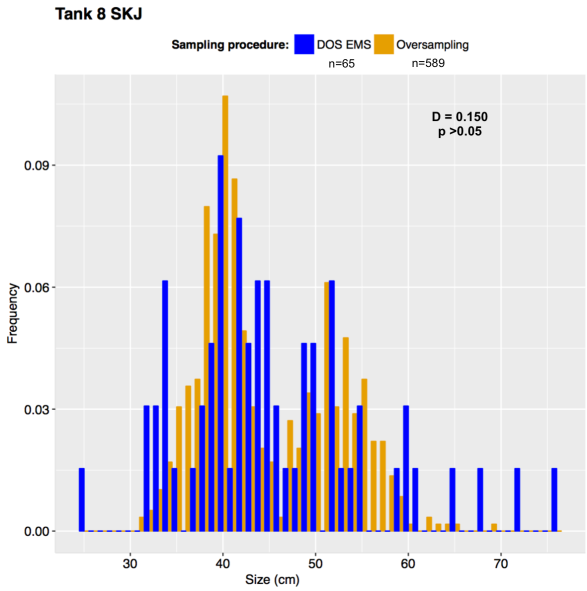
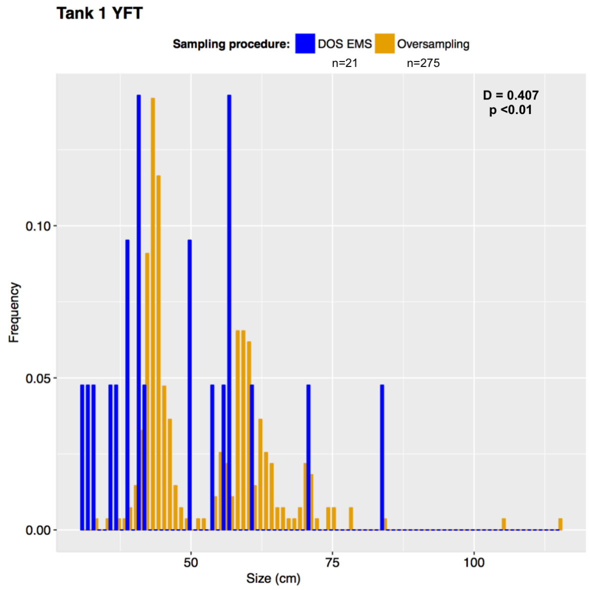
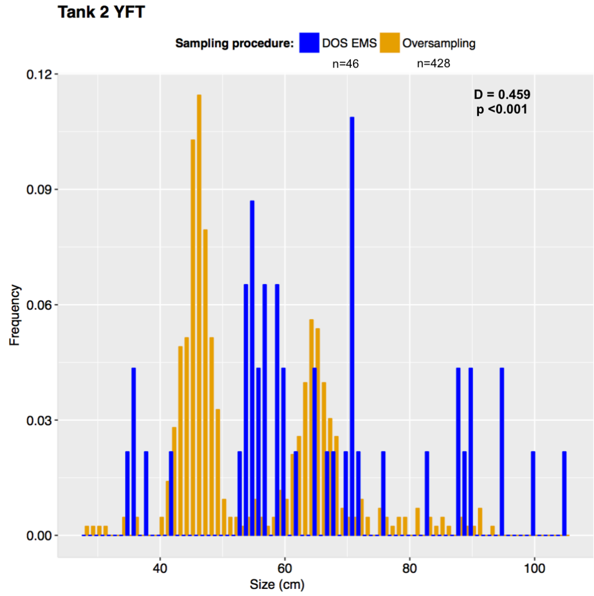
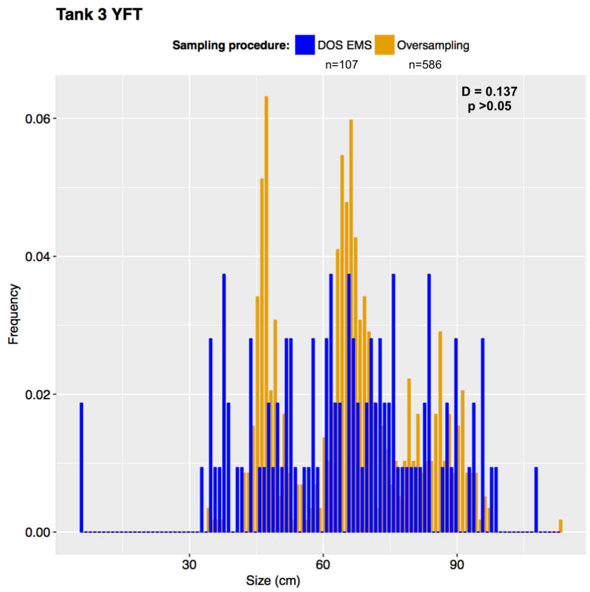
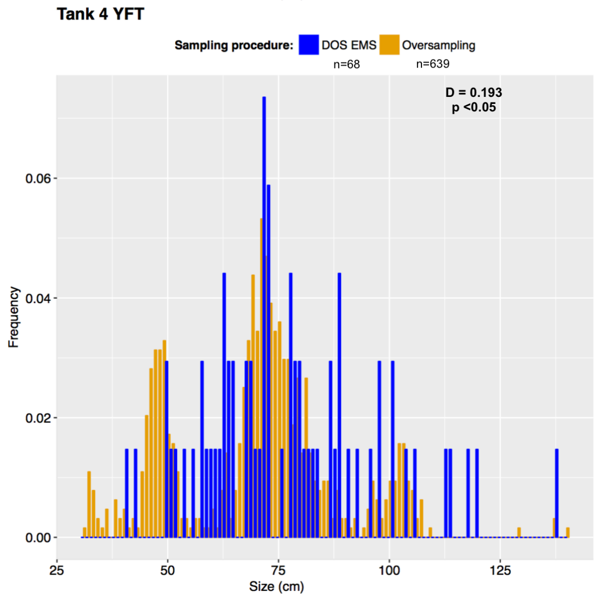


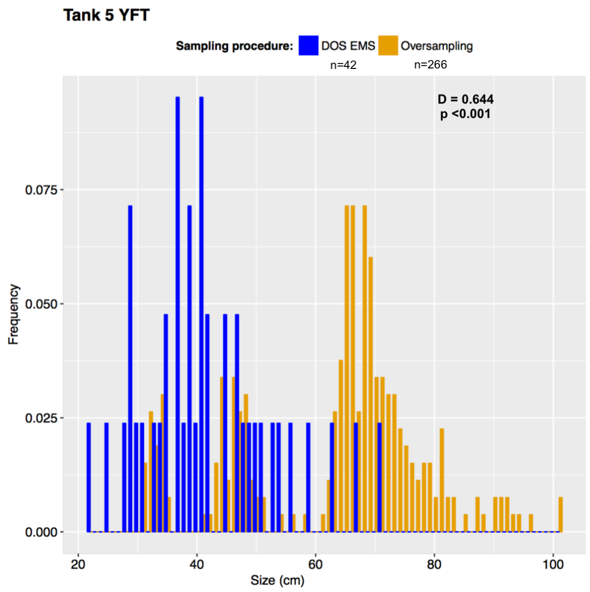
Figure 43: Size frequency histograms of skipjack tuna (SKJ) by tank for Oversampling and DOS EMS S1 procedures. n indicates the number of individuals measured by each procedure. D statistic and P-value of the Kolmogorov-Smirnov test are indicated.

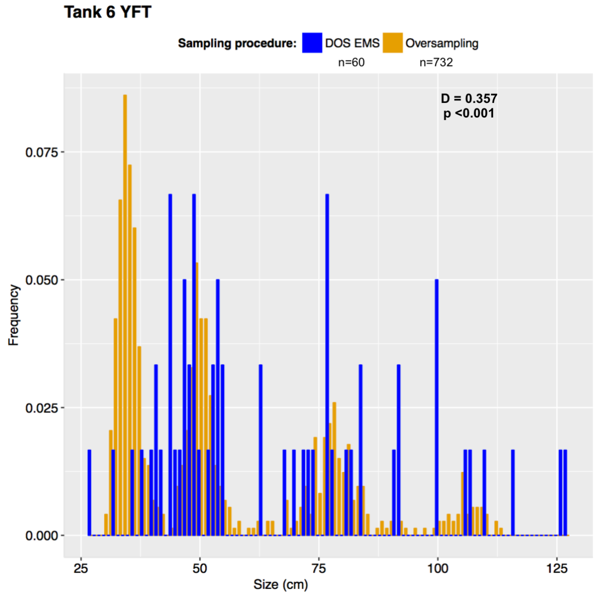

Tank 1 YFT
Sampling procedure: DOS EMS Oversampling
n=21 n=275
D = 0.407
p <0.01
Frequency
Size (cm)


Tank 2 YFT
Sampling procedure: DOS EMS Oversampling
n=46 n=428
D = 0.459
p <0.001
Frequency
Size (cm)


Tank 3 YFT
Sampling procedure: DOS EMS Oversampling
n=107 n=586
D = 0.137
p >0.05
Frequency
Size (cm)


Tank 4 YFT
Sampling procedure: DOS EMS Oversampling
n=68 n=639
D = 0.193
p <0.05
Frequency
Size (cm)


Tank 5 YFT
Sampling procedure: DOS EMS Oversampling
n=42 n=266
D = 0.644
p <0.001
Frequency
Size (cm)


Tank 6 YFT
Sampling procedure: DOS EMS Oversampling
n=60 n=732
D = 0.357
p <0.001
Frequency
Size (cm)

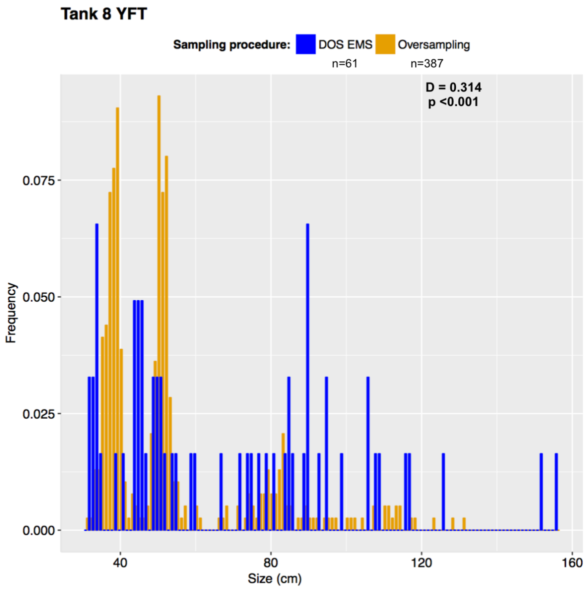
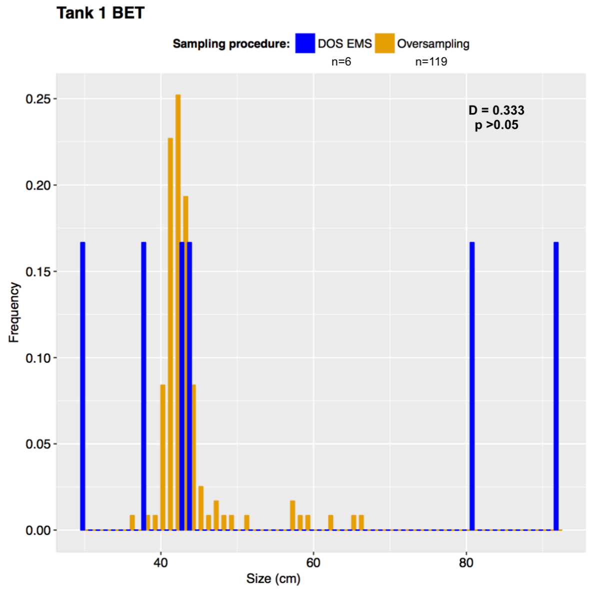
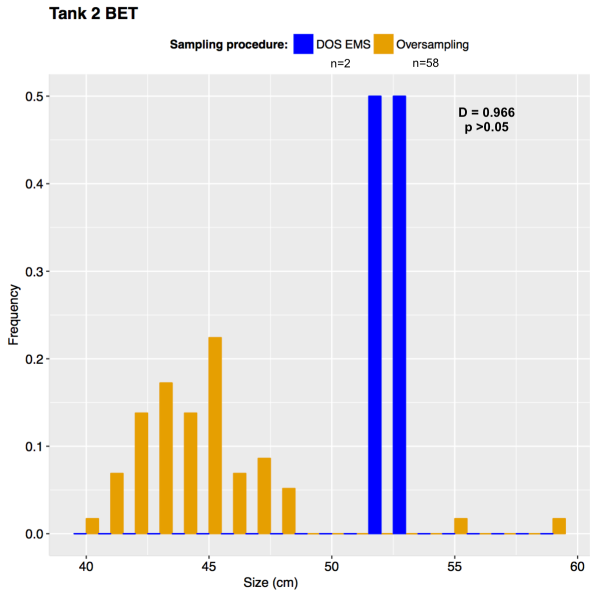
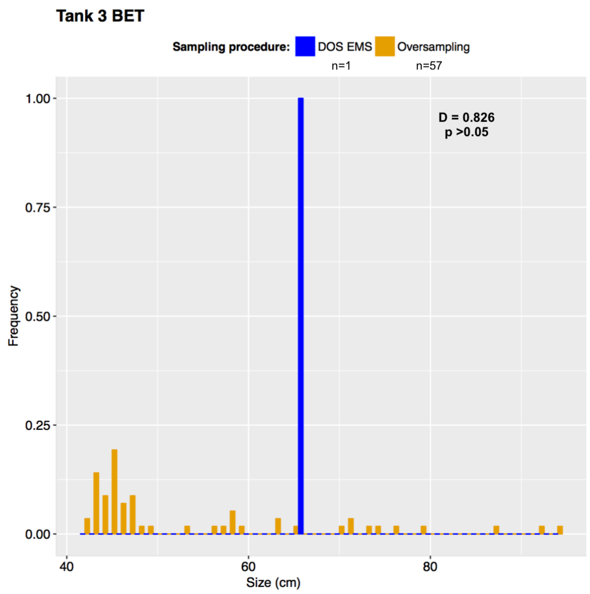
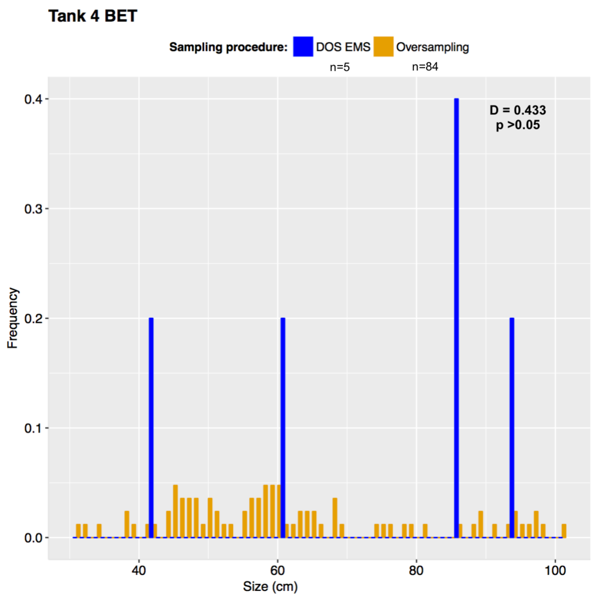


Figure 44: Size frequency histograms of yellowfin tuna (YFT) by tank for Oversampling and DOS EMS S1 procedures. n indicates the number of individuals measured by each procedure. D statistic and P-value of the Kolmogorov-Smirnov test are indicated.


Tank 1 BET
Sampling procedure: DOS EMS Oversampling
n=6 n=119
D = 0.333
p >0.05
Frequency
Size (cm)


Tank 2 BET
Sampling procedure: DOS EMS Oversampling
n=2 n=58
D = 0.966
p >0.05
Frequency
Size (cm)


Tank 3 BET
Sampling procedure: DOS EMS Oversampling
n=1 n=57
D = 0.826
p >0.05
Frequency
Size (cm)


Tank 4 BET
Sampling procedure: DOS EMS Oversampling
n=5 n=84
D = 0.433
p >0.05
Frequency
Size (cm)

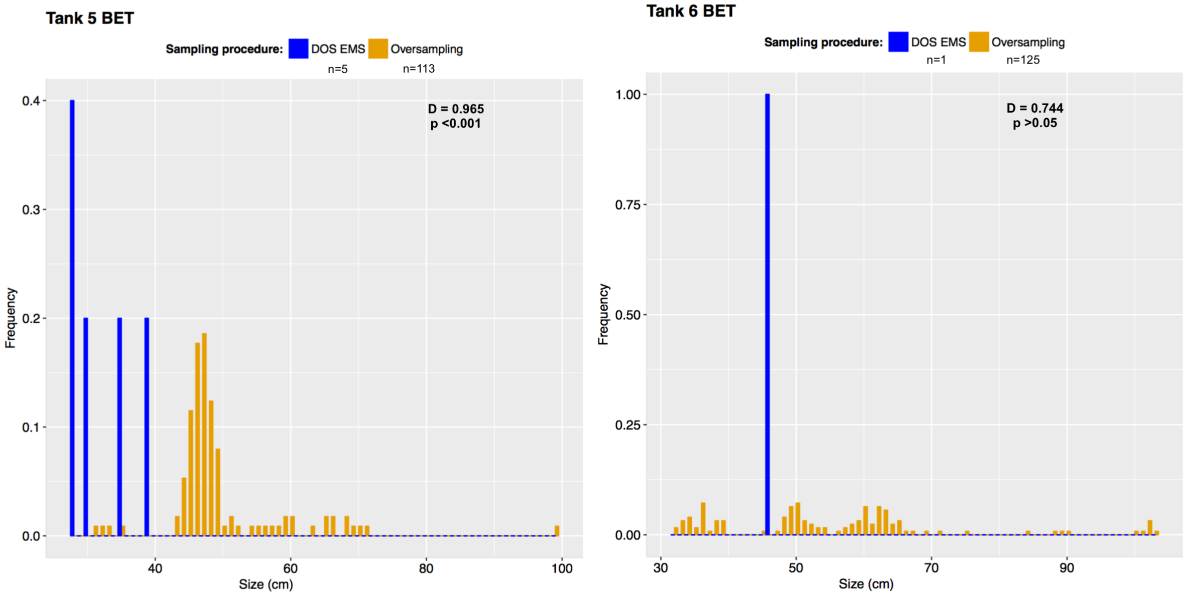


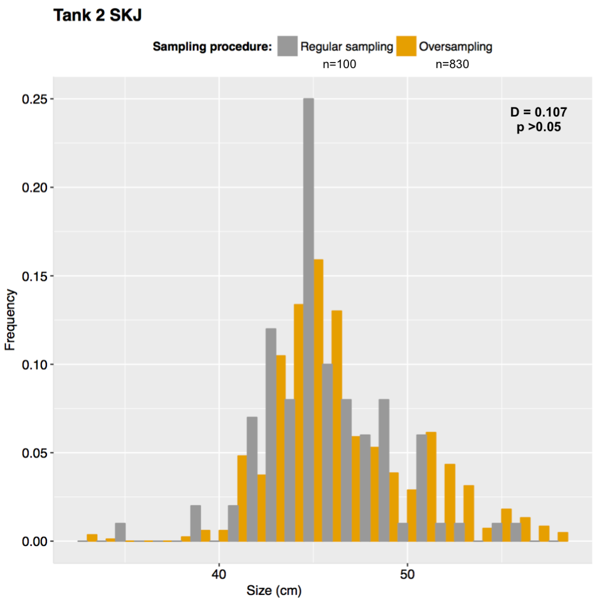
Figure 45: Size frequency histograms of bigeye tuna (BET) by tank for Oversampling and DOS EMS S1 procedures. n indicates the number of individuals measured by each procedure. D statistic and P-value of the Kolmogorov-Smirnov test are indicated.

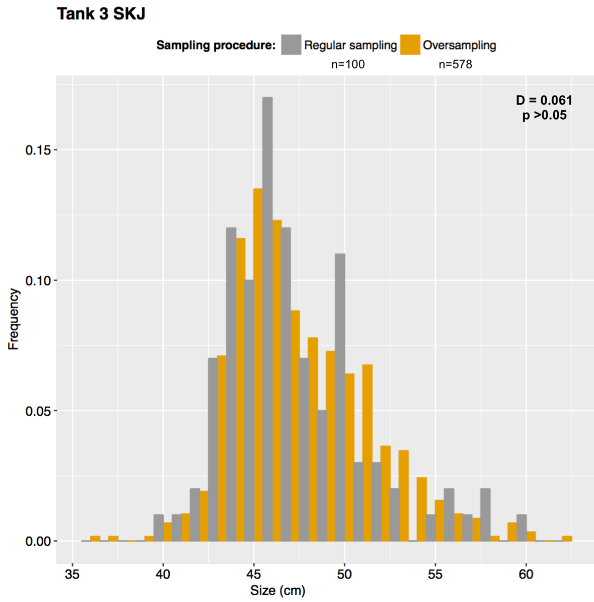
Comparison between Oversampling and Regular sampling

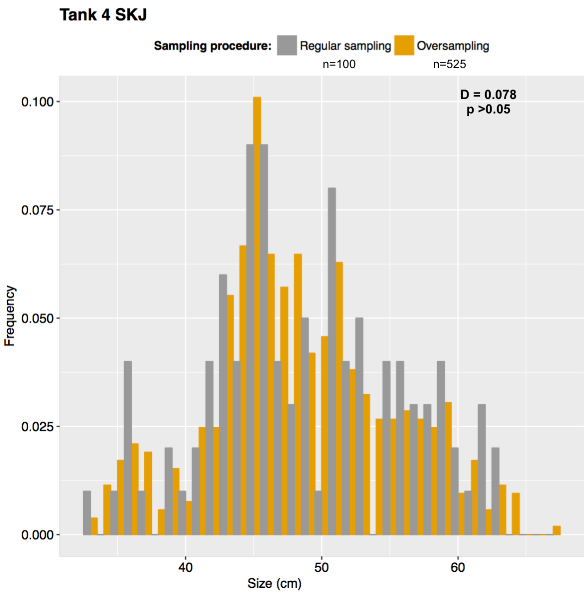
The comparisons yield very good results between oversampling and regular sampling for fish size distribution of the catch of skipjack tuna. The general trend that is shown on the graphs (*Figure 46*) is that regular sampling follow the same distribution as oversampling for skipjack tuna.

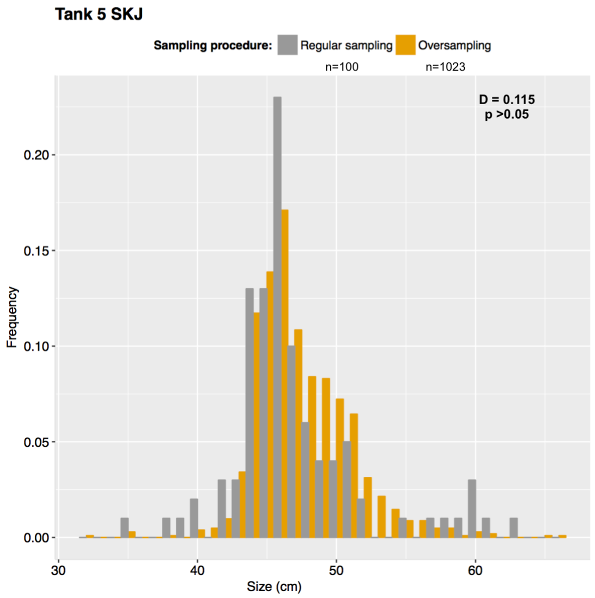
The comparisons did not yield good results between oversampling and regular sampling for fish size distribution of the catch of yellowfin tuna, with most of them showing significant differences between the two methods (Tank 2, Tank 4, Tank 5, Tank 6 and Tank 8). The general trend that is shown on the graphs (*Figure 47*) is that regular sampling does not follow the same distribution as oversampling for yellowfin tuna.

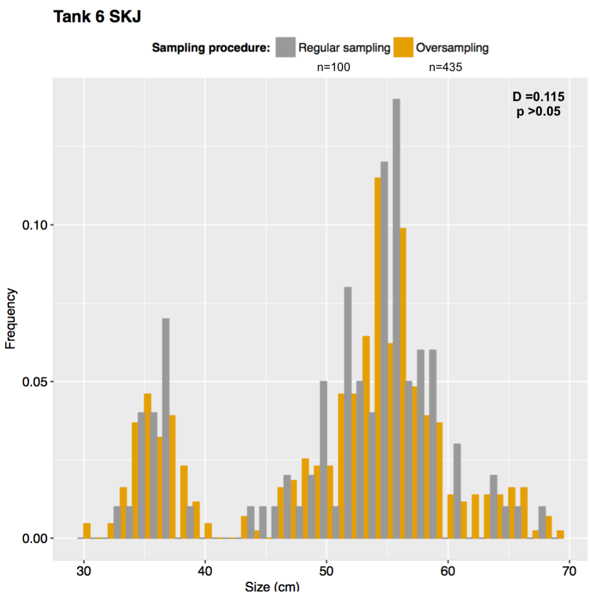
The comparisons yield very good results between oversampling and regular sampling for fish size distribution of the catch of bigeye tuna. The general trend that is shown on the graphs (*Figure 48*) is that regular sampling follow more or less the same distribution as oversampling for bigeye tuna.

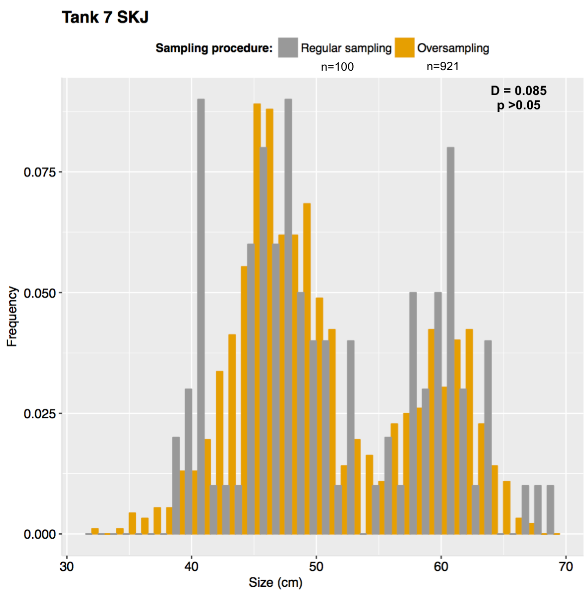

Tank 2 SKJ
Sampling procedure:
Regular sampling
n=100
Oversampling
n=830
D = 0.107
p >0.05
Frequency
Size (cm)


Tank 3 SKJ
Sampling procedure:
Regular sampling
n=100
Oversampling
n=578
D = 0.061
p >0.05
Frequency
Size (cm)


Tank 4 SKJ
Sampling procedure:
Regular sampling
n=100
Oversampling
n=525
D = 0.078
p >0.05
Frequency
Size (cm)


Tank 5 SKJ
Sampling procedure:
Regular sampling
n=100
Oversampling
n=1023
D = 0.115
p >0.05
Frequency
Size (cm)


Tank 6 SKJ
Sampling procedure:
Regular sampling
n=100
Oversampling
n=435
D =0.115
p >0.05
Frequency
Size (cm)


Tank 7 SKJ
Sampling procedure:
Regular sampling
n=100
Oversampling
n=921
D = 0.085
p >0.05
Frequency
Size (cm)

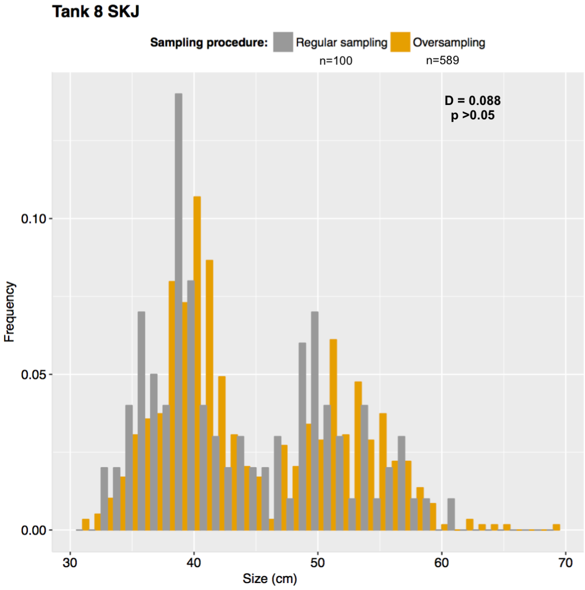
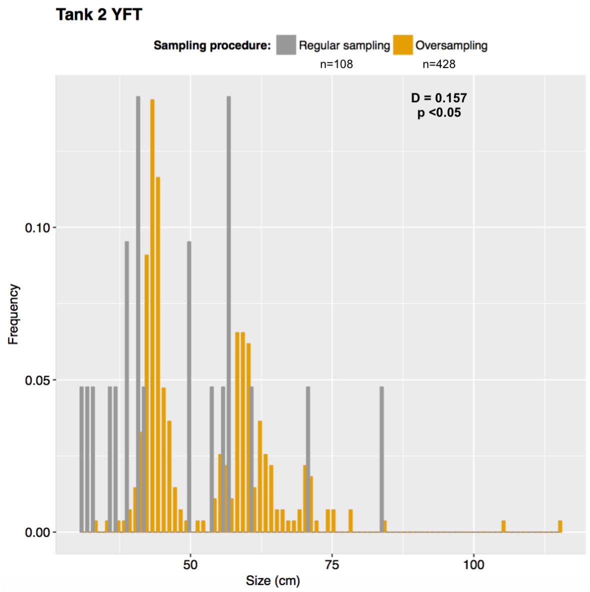
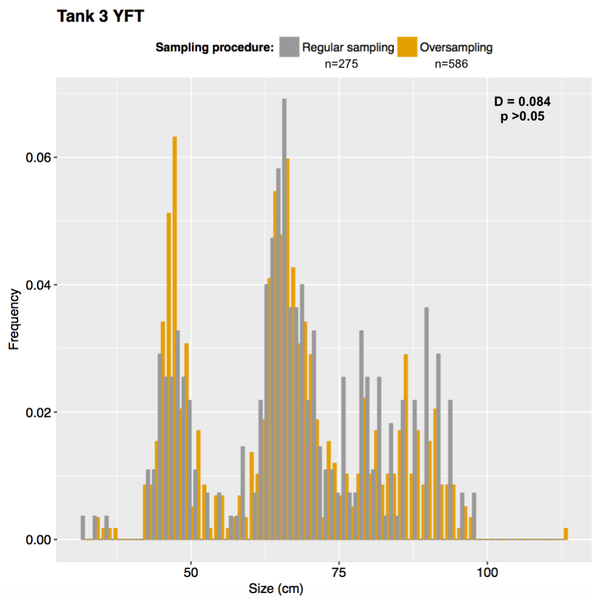
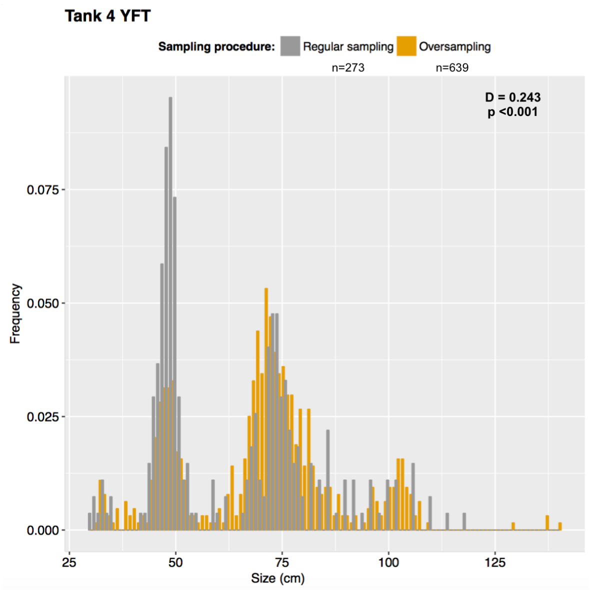
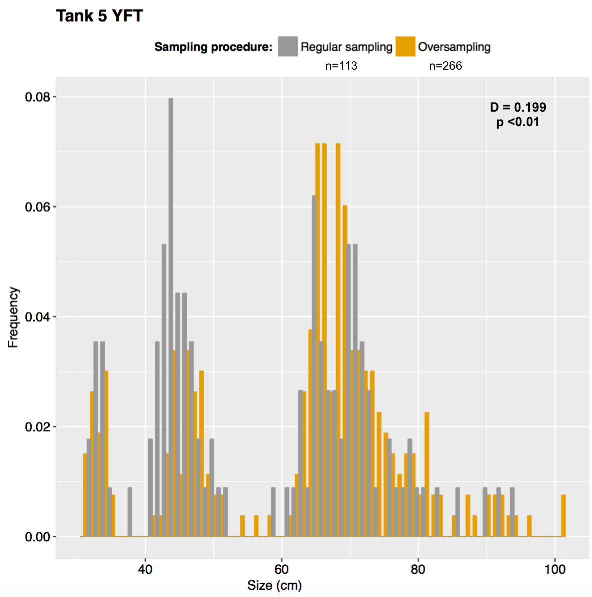


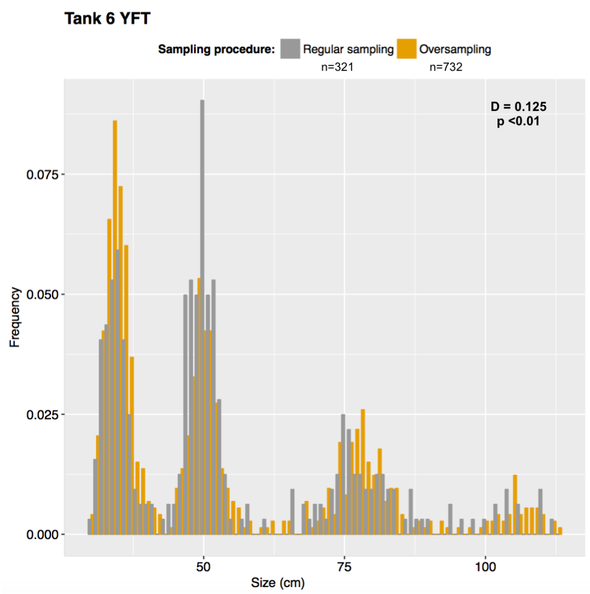
Figure 46: Size frequency histograms of skipjack tuna (SKJ) by tank for Oversampling and Regular sampling procedures. n indicates the number of individuals measured by each procedure. D statistic and P-value of the Kolmogorov-Smirnov test are indicated.

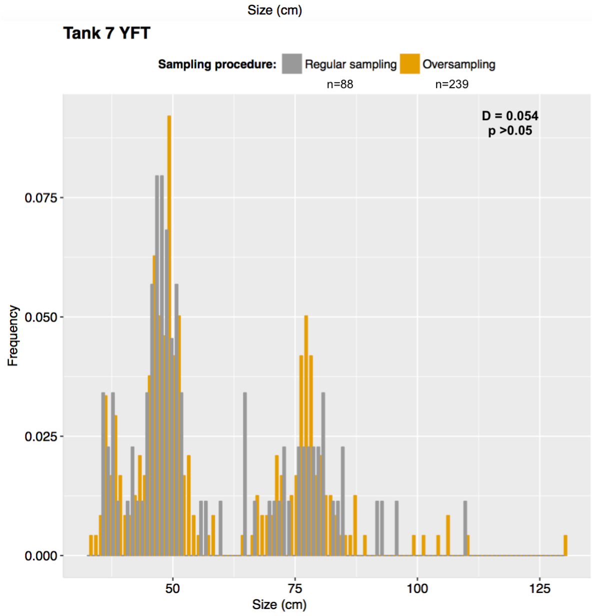

Tank 2 YFT
Sampling procedure: Regular sampling n=108 Oversampling n=428
D = 0.157
p <0.05
Frequency
0.00
0.05
0.10
50
75
100
Size (cm)


Tank 3 YFT
Sampling procedure: Regular sampling n=275 Oversampling n=586
D = 0.084
p >0.05
Frequency
0.00
0.02
0.04
0.06
50
75
100
Size (cm)


Tank 4 YFT
Sampling procedure: Regular sampling n=273 Oversampling n=639
D = 0.243
p <0.001
Frequency
0.000
0.025
0.050
0.075
25
50
75
100
125
Size (cm)


Tank 5 YFT
Sampling procedure: Regular sampling n=113 Oversampling n=266
D = 0.199
p <0.01
Frequency
0.00
0.02
0.04
0.06
0.08
40
60
80
100
Size (cm)


Tank 6 YFT
Sampling procedure: Regular sampling n=321 Oversampling n=732
D = 0.125
p <0.01
Frequency
0.000
0.025
0.050
0.075
50
75
100
Size (cm)


Tank 7 YFT
Sampling procedure: Regular sampling n=88 Oversampling n=239
D = 0.054
p >0.05
Frequency
0.000
0.025
0.050
0.075
50
75
100
125
Size (cm)

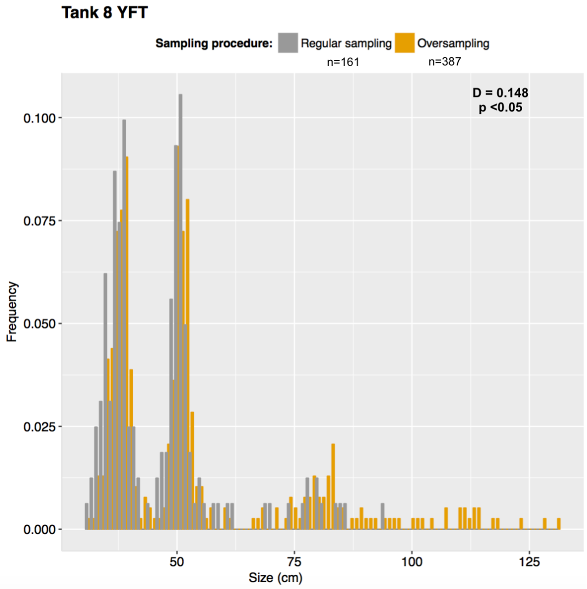
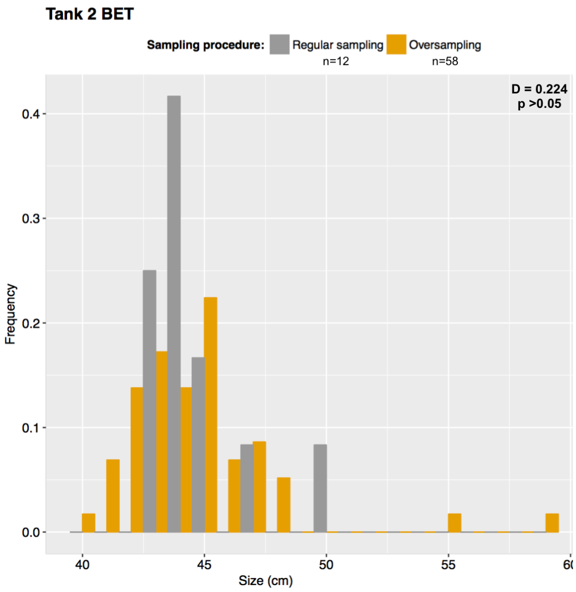
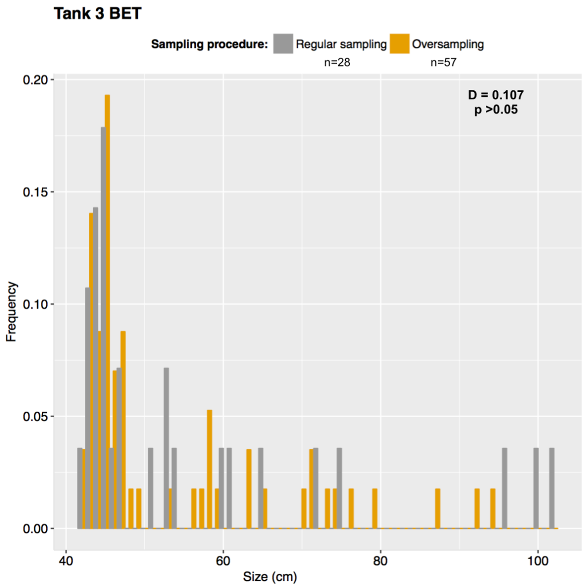
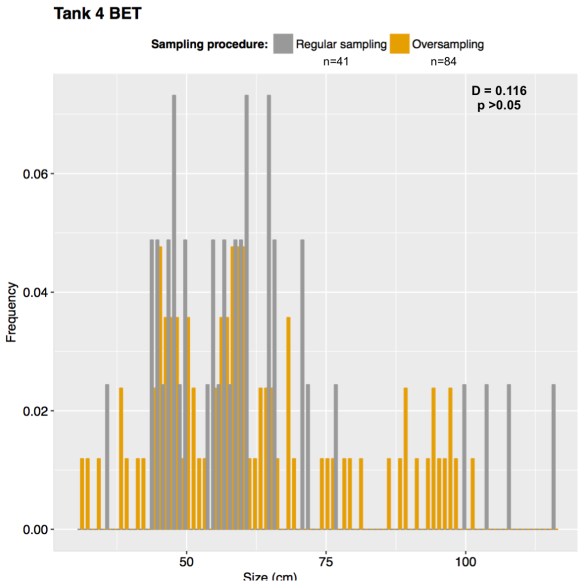
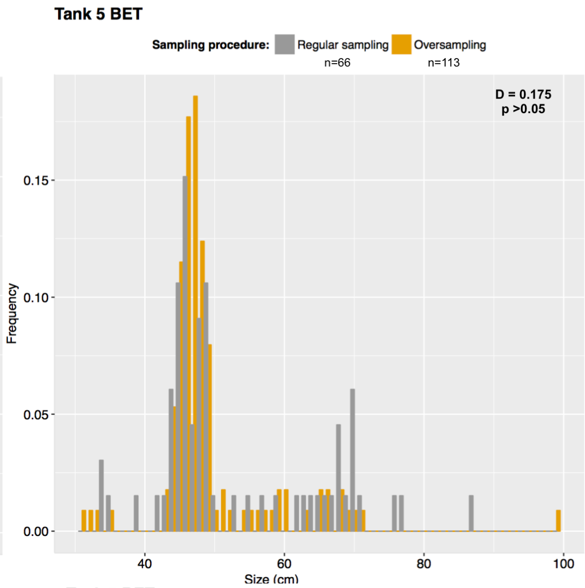


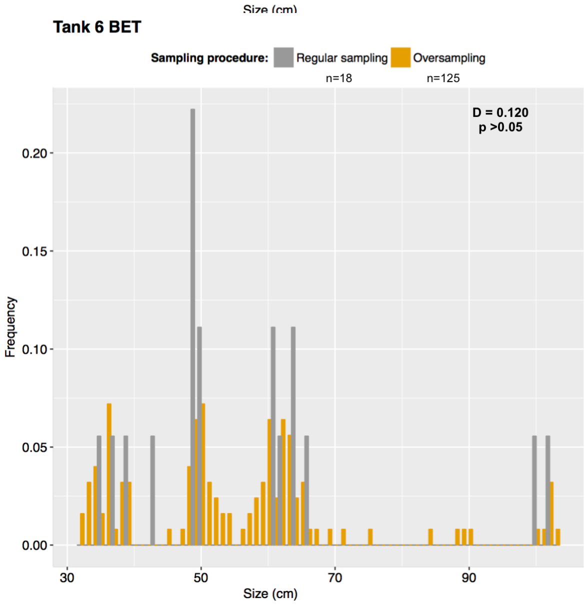
Figure 47: Size frequency histograms of yellowfin tuna (YFT) by tank for Oversampling and Regular sampling procedures. n indicates the number of individuals measured by each procedure. D statistic and P-value of the Kolmogorov-Smirnov test are indicated.

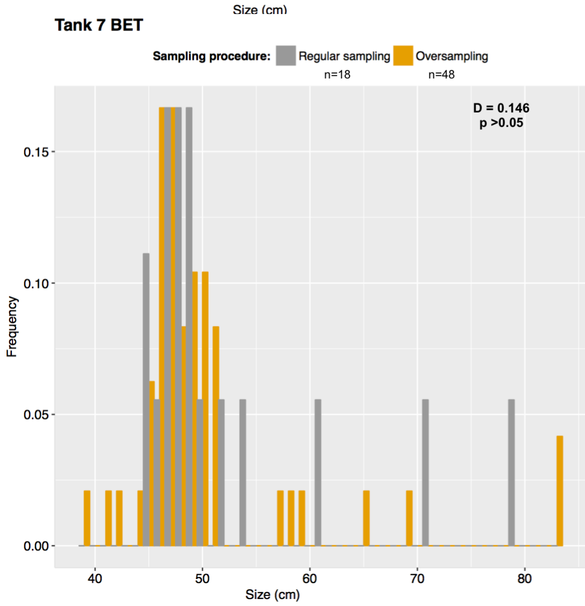

Tank 2 BET
Sampling procedure: Regular sampling n=12 Oversampling n=58
D = 0.224
p >0.05
Frequency
Size (cm)


Tank 3 BET
Sampling procedure: Regular sampling n=28 Oversampling n=57
D = 0.107
p >0.05
Frequency
Size (cm)


Tank 4 BET
Sampling procedure: Regular sampling n=41 Oversampling n=84
D = 0.116
p >0.05
Frequency
Size (cm)


Tank 5 BET
Sampling procedure: Regular sampling n=66 Oversampling n=113
D = 0.175
p >0.05
Frequency
Size (cm)


Tank 6 BET
Sampling procedure: Regular sampling n=18 Oversampling n=125
D = 0.120
p >0.05
Frequency
Size (cm)


Tank 7 BET
Sampling procedure: Regular sampling n=18 Oversampling n=48
D = 0.146
p >0.05
Frequency
Size (cm)

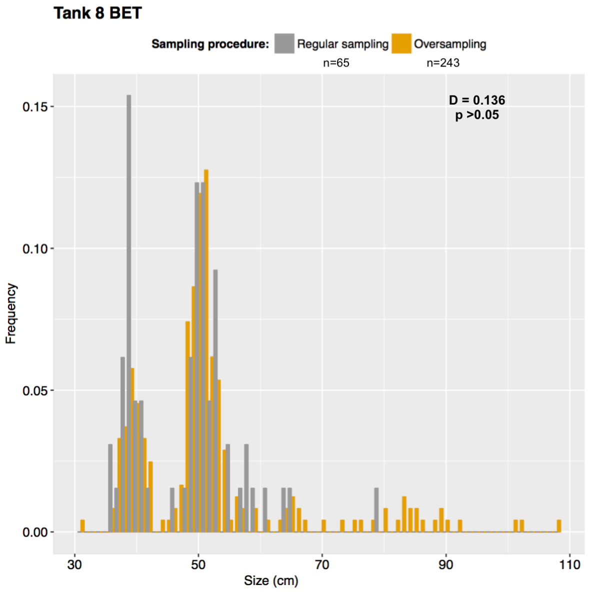


Figure 48: Size frequency histograms of bigeye tuna (BET) by tank for Oversampling and Regular sampling procedures. n indicates the number of individuals measured by each procedure. D statistic and P-value of the Kolmogorov-Smirnov test are indicated.

3.4 Discarded Tuna

One of the specific tasks of the study was to evaluate the reliability of EMS to estimate total discarded tuna catch and discarded tuna catch by species and/or size by trip, by comparing data collected using EMS to the data collected by scientific observers. However, no discarded tuna was reported by SFA dry observers and scientific observer recorded discarded tuna only on trip 6, a total of 0.2 MT of skipjack tuna. Therefore, because there was not enough data available, it was not possible to perform this specific task to verify whether or not EMS could accurately estimate discarded tuna.

3.5 Bycatch

The specific tasks of the study were to (1) evaluate the reliability of EMS to estimate total bycatch by fish tank, by comparing data collected using EMS to the data collected from oversampling of catches in port from selected fish wells and (2) evaluate the reliability of EMS to estimate total bycatch, total retained bycatch and total discarded bycatch by trip, by comparing the data collected using EMS to the data collected by scientific observers. Unfortunately, it was not possible to perform any of the two tasks. This was because DOS and SFA dry observers could not ensure a correct counting of bycatch species dropping into selected fish wells from EMS video footages. Thus, no analysis could be performed with the oversampling by-catch data (*Table 53*). Furthermore, bycatch trip data that was made available by SFA dry observers was incomplete and bycatch trip data provided by scientific observers was underestimated (*Table 54*). Nevertheless, it was possible to create a summary table to show the comparison between SFA EMS and Scientific Observer Programme for total bycatch (in number) by trip (*Table 55*). Out of ten fishing trips only seven trips data were made available. It shows that in most fishing trips, SFA dry observers constantly underestimate total bycatch compared to the Scientific Observer Programme, except for trip four which clearly shows that the scientific observer did not do a proper job.

Table 53:Total number and corresponding weight of retained bycatch species from oversampled fish wells.

Fishing Trip	Fish Tank	Total Number	Total Weight (MT)
2	1	149	2.328
3	2	176	4.068
4	3	442	12.505
5	4	332	9.506
6	5	292	8.163
7	6	352	11.177
8	7	617	6.29
9	8	910	20.799

Table 54: Summary of bycatch data collected by the Scientific Observer Programme for nine of the ten fishing trips.

Fishing Trip	Total Bycatch (MT)	Discards (MT)	Retained (MT)
1	3.364	1.159	2.205
2	4.967	3.667	1.3
3	8.265	3.06	5.205
4	1.595	1.331	0.264
5	10.077	8.133	1.944
6	15.059	8.04	7.02
7	9.041	5.758	3.283
8	4.066	1.622	2.444
10	8.801	5.127	3.674

Table 55: Comparisons between SFA EMS (SFA) and Scientific Observer Programme (Sea.O) for Total Bycatch by species group for seven of ten fishing trips.

Trip 1		
Bycatch	**Sea. O**	**SFA**
Billfishes	4	0
Other bony fishes	528	40
Rays	1	1
Sharks	62	43
	595	**84**

Trip 2		
Bycatch	**Sea. O**	**SFA**
Billfishes	26	19
Other bony fishes	1677	304
Sharks	68	48
	1771	**371**

Trip 3		
Bycatch	**Sea. O**	**SFA**
Billfishes	7	2
Other bony fishes	2337	181
Rays	0	1
Sharks	231	114
	2575	**298**

Trip 4		
Bycatch	**Sea. O**	**SFA**
Billfishes	9	3
Other bony fishes	0	178
Rays	3	0
Sharks	160	90
Turtles	1	0
	173	**271**

Trip 5		
Bycatch	**Sea. O**	**SFA**
Billfishes	15	7
Other bony fishes	3104	786
Sharks	176	82
Turtles	3	1
	3298	**876**

Trip 6		
Bycatch	**Sea. O**	**SFA**
Billfishes	20	11
Other bony fishes	3336	317
Rays	0	0
Sharks	308	165
	3664	**493**

Trip 7		
Bycatch	**Sea. O**	**SFA**
Billfishes	12	6
Other bony fishes	3075	182
Rays	1	1
Sharks	78	13
	3166	**202**

3.6 Summary of Results

The tables (56-69) below show the summary of results for the comparisons between sampling methods for each measured variable. The main results of the study are depicted by letter 'M' (main text) and other results are depicted my letter 'A' (appendix). The results of the analysis are graded in colours, green is a good match, yellow is a fair match and red is a poor match. For the comparison of catch for retained tuna, a good match means that the agreement between the two methods was very good or good, a fair match means that the agreement between the two methods was moderate or average and a poor match means that the agreement between the two methods was poor/invalid. For the comparison of species and size composition for retained tuna, a good match is from 70 to 100%, a fair match is from 50 to 69% and a poor match is from 0 to 49%. In addition, white colour indicates not enough data. A minimum of five tanks were used to grade the results of the analysis.

Table 56: Summary of results for the comparison between sampling methods for total retained tuna by fish tank (good match (green), fair match (yellow), poor match (red), results are in main text (M) and results are in appendix (A). Good match indicates a very good or good agreement between methods. Fair match indicates a moderate or average agreement between methods. Poor match indicates poor/invalid agreement between methods.

	DOS EMS S1	DOS EMS S2	SFA EMS	Oversampling EU	Oversampling IOTC	Scientific Observer Programme	Well-map
DOS EMS S1							
DOS EMS S2	A						
SFA EMS	A	A					
Oversampling EU	M	A	A				
Oversampling IOTC	M	A	A				
Scientific Observer Programme	A	A	A	A	A		
Well-map	A	A	A	M	M	A	

Table 57: Summary of results for the comparison between sampling methods for total retained skipjack tuna by fish tank (good match (green), fair match (yellow), poor match (red), results are in main text (M) and results are in appendix (A)). Good match indicates a very good or good agreement between methods. Fair match indicates a moderate or average agreement between methods. Poor match indicates poor/invalid agreement between methods.

	DOS EMS S1	DOS EMS S2	SFA EMS	Oversampling EU	Oversampling IOTC	Scientific Observer Programme	Well-map
DOS EMS S1							
DOS EMS S2	A						
SFA EMS	A	A					
Oversampling EU	M	A	A				
Oversampling IOTC	M	A	A				
Scientific Observer Programme	A	A	A	A	A		
Well-map	A	A	A	M	M	A	

Table 58: Summary of results for the comparison between sampling methods for total retained yellowfin tuna by fish tank (good match (green), fair match (yellow), poor match (red), results are in main text (M) and results are in appendix (A)). Good match indicates a very good or good agreement between methods. Fair match indicates a moderate or average agreement between methods. Poor match indicates poor/invalid agreement between methods.

	DOS EMS S1	DOS EMS S2	SFA EMS	Oversampling EU	Oversampling IOTC	Scientific Observer Programme	Well-map
DOS EMS S1							
DOS EMS S2	A						
SFA EMS	A	A					
Oversampling EU	M	A	A				
Oversampling IOTC	M	A	A				
Scientific Observer Programme	A	A	A	A	A		
Well-map	A	A	A	M	M	A	

Table 59: Summary of results for the comparison between sampling methods for total retained bigeye tuna by fish tank (good match (green), fair match (yellow), poor match (red), results are in main text (M) and results are in appendix (A)). Good match indicates a very good or good agreement between methods. Fair match indicates a moderate or average agreement between methods. Poor match indicates poor/invalid agreement between methods.

	DOS EMS S1	DOS EMS S2	SFA EMS	Oversampling EU	Oversampling IOTC	Scientific Observer Programme	Well-map
DOS EMS S1							
DOS EMS S2	A						
SFA EMS	A	A					
Oversampling EU	M	A	A				
Oversampling IOTC	M	A	A				
Scientific Observer Programme	A	A	A	A	A		
Well-map	A	A	A	M	M	A	

Table 60: Summary of results for the comparison between sampling methods for total retained tuna by trip (good match (green), fair match (yellow), poor match (red), results are in main text (M) and results are in appendix (A)). Good match indicates a very good or good agreement between methods. Fair match indicates a moderate or average agreement between methods. Poor match indicates poor/invalid agreement between methods.

	SFA EMS	Scientific Observer Programme	Logbook	Well-map	Unloading
SFA EMS					
Scientific Observer Programme	A				
Logbook	A	A			
Well-map	A	A	A		
Unloading	M	A	M	M	

Table 61: Summary of results for the comparison between sampling methods for total retained skipjack tuna and by trip (good match (green), fair match (yellow), poor match (red), results are in main text (M) and results are in appendix (A)). Good match indicates a very good or good agreement between methods. Fair match indicates a moderate or average agreement between methods. Poor match indicates poor/invalid agreement between methods.

	SFA EMS	Scientific Observer Programme	Logbook	Well-map	Unloading
SFA EMS					
Scientific Observer Programme	A				
Logbook	A	A			
Well-map	A	A	A		
Unloading	M	A	M	M	

Table 62: Summary of results for the comparison between sampling methods for total retained yellowfin tuna and by trip (good match (green), fair match (yellow), poor match (red), results are in main text (M) and results are in appendix (A)). Good match indicates a very good or good agreement between methods. Fair match indicates a moderate or average agreement between methods. Poor match indicates poor/invalid agreement between methods.

	SFA EMS	Scientific Observer Programme	Logbook	Well-map	Unloading
SFA EMS					
Scientific Observer Programme	A				
Logbook	A	A			
Well-map	A	A	A		
Unloading	M	A	M	M	

Table 63: Summary of results for the comparison between sampling methods for total retained bigeye tuna and by trip (good match (green), fair match (yellow), poor match (red), results are in main text (M) and results are in appendix (A)). Good match indicates a very good or good agreement between methods. Fair match indicates a moderate or average agreement between methods. Poor match indicates poor/invalid agreement between methods.

	SFA EMS	Scientific Observer Programme	Logbook	Well-map	Unloading
SFA EMS					
Scientific Observer Programme	A				
Logbook	A	A			
Well-map	A	A	A		
Unloading	M	A	M	M	

Table 64: Summary of results for the comparison between sampling methods for proportion of tuna species by fish tank (good match (green), fair match (yellow), poor match (red), results are in main text (M) and results are in appendix (A)). Good match is from 70 to 100%. Fair match is from 50 to 69%. Poor match is from 0 to 49%.

	DOS EMS S1	DOS EMS S2	SFA EMS	Oversampling EU	Oversampling IOTC	Regular Sampling EU	Regular Sampling IOTC	Scientific Observer Programme	Well-map
DOS EMS S1									
DOS EMS S2	A								
SFA EMS	A	A							
Oversampling EU	M	A	A						
Oversampling IOTC	M	A	A						
Regular Sampling EU	A	A	A	M					
Regular Sampling IOTC	A	A	A		M				
Scientific Observer Programme	A	A	A	A	A	A	A		
Well-map	A	A	A	M	M	A	A	A	

Table 65: Summary of results for the comparison between sampling methods for yellowfin tuna size composition by fish tank (good match (green), fair match (yellow), poor match (red), not enough data (white), results are in main text (M) and results are in appendix (A)). Good match is from 70 to 100%. Fair match is from 50 to 69%. Poor match is from 0 to 49%.

	DOS EMS S1	DOS EMS S2	Oversampling EU	Oversampling IOTC	Regular Sampling EU	Regular Sampling IOTC	Scientific Observer Programme	Well-map
DOS EMS S1								
DOS EMS S2	A							
Oversampling EU	M	A						
Oversampling IOTC	M	A						
Regular Sampling EU	A	A	M					
Regular Sampling IOTC	A	A		M				
Scientific Observer Programme	A	A	A	A	A	A		
Well-map	A	A	M	M	A	A	A	

Table 66: Summary of results for the comparison between sampling methods for bigeye tuna size composition by fish tank (good match (green), fair match (yellow), poor match (red), not enough data (white), results are in main text (M) and results are in appendix (A)). Good match is from 70 to 100%. Fair match is from 50 to 69%. Poor match is from 0 to 49%.

	DOS EMS S1	DOS EMS S2	Oversampling EU	Oversampling IOTC	Regular Sampling EU	Regular Sampling IOTC	Scientific Observer Programme	Well-map
DOS EMS S1								
DOS EMS S2	A							
Oversampling EU	M	A						
Oversampling IOTC	M	A						
Regular Sampling EU	A	A	M					
Regular Sampling IOTC	A	A		M				
Scientific Observer Programme	A	A	A	A	A	A		
Well-map	A	A	M	M	A	A	A	

Table 67: Summary of results for the comparison between sampling methods for species composition by trip (good match (green), fair match (yellow), poor match (red), results are in main text (M) and results are in appendix (A)). Good match is from 70 to 100%. Fair match is from 50 to 69%. Poor match is from 0 to 49%.

	SFA EMS	Scientific Observer Programme	Logbook	Well-map	Unloading
SFA EMS					
Scientific Observer Programme	A				
Logbook	M	A			
Well-map	M	A	M		
Unloading	M	A	M	M	

Table 68: Summary of results for the comparison between sampling methods for yellowfin tuna size composition by trip (good match (green), fair match (yellow), poor match (red), results are in main text (M) and results are in appendix (A)). Good match is from 70 to 100%. Fair match is from 50 to 69%. Poor match is from 0 to 49%.

	Logbook	Well-map	Unloading
Logbook			
Well-map	M		
Unloading	M	M	

Table 69: Summary of results for the comparison between sampling methods for bigeye tuna size composition by trip (good match (green), fair match (yellow), poor match (red), results are in main text (M) and results are in appendix (A)). Good match is from 70 to 100%. Fair match is from 50 to 69%. Poor match is from 0 to 49%.

	Logbook	Well-map	Unloading
Logbook			
Well-map	M		
Unloading	M	M	

4 Discussion

In order to prove that EMS is a viable tool for the monitoring of fisheries activities and collecting fisheries related information, there is a need to count on qualified dry observers to review and analyse recorded data. Unexperienced dry observers producing poor analyses can lead to false interpretation of results and this can have a negative impact on the use of EMS as a monitoring tool. In this research study, results have shown that experienced dry observers performed better while less experienced dry observers performed poorly. This problem can be solved with appropriate training and constant supervision.

Based on the analyses performed by the most qualified dry observers, EMS is capable of monitoring retained tuna catch to some extent. EMS was able to estimate proportion of tuna species by fish tank. It was also able to estimate total retained skipjack tuna catch and total retained yellowfin tuna catch. However, it failed to estimate total retained bigeye tuna catch by fish tank. It also failed to assess the fish size frequency distributions of the catch of the three species. The main reason for such findings could be due to position of the cameras. DOS confirmed that some of the cameras on the lower deck were displaced during the time of the project and this could have affected the results as they were calibrated at the start of the project according to a specific position and referenced on board as measuring scale. Furthermore, the three analyses proved that the sample size for bigeye tuna was too low to allow good comparisons between EMS and oversampling procedures. This could be because bigeye tuna accounts for a relatively small proportion of the total catch in the region (Gillett, 2013). A clear source of bias in the analysis was in the proportion of yellowfin tuna and bigeye tuna by commercial size category by fish tank, dry observers measured more of the large (+10 kg) yellowfin tuna and bigeye tuna and less of the small (-10 kg) yellowfin tuna and bigeye tuna than oversampling. This may be due to dry observers selecting more large specimens of large yellowfin tuna and bigeye tuna for the sampling. For instance, when reviewing and analysing a specific video frame it is much easier for them to see and record all the large fish, while only counting some of the small fish, as some of them may be hidden under the pile of fish.

SFA dry observers were able to estimate total retained skipjack tuna catch and to some extent total retained yellowfin tuna catch, but failed to estimate total retained bigeye tuna catch by trip. It also failed to estimate proportion of tuna species and proportion of yellowfin tuna and bigeye tuna by commercial size category by trip. Therefore, because SFA dry observers were the less experienced group of dry observers who reviewed and analysed the data, their results cannot be used to evaluate the reliability of EMS to estimate total retained tuna catch, retained tuna catch by species and size by trip.

The regular sampling procedure was able to assess the fish size frequency distributions of the catch of skipjack tuna and bigeye tuna but failed to assess the fish size frequency distributions of the catch of yellowfin tuna by fish tank. Furthermore, it was able to estimate the proportion of tuna species and proportion of bigeye tuna by commercial size category by fish tank but to some extent. It was not able to estimate the proportion of yellowfin tuna by commercial size category by fish tank. This shows that the sample size was too low to estimate yellowfin tuna per fish tank especially in fish wells containing mixed fish (mainly dominated by small specimens but with some large fish) from FAD sets due to its heterogeneity. According to Laurec cited in ICCAT (2010) "*in a tank fish species and fish lengths tend not to be evenly distributed from the surface down to the bottom of a well. Such a layering effect may be due to (at least) two phenomena; physical causes which may generate a vertical sorting, on the basis of length and species, and fish well containing various fishing sets with different fish typologies* *in terms of species composition and/or length distribution*" This problem may be solved by increasing sample size in regular sampling at least for yellowfin tuna. Data from this study did not indicate that it will be necessary to increase sampling size of regular sampling for the other two species but it could not be disregarded for bigeye in some particular sets due to its size range.

Chief engineers (responsible for completing well-map) were able to estimate total retained skipjack tuna catch by fish tank. They were able to estimate total retained tuna catch and total retained yellowfin tuna catch to some extent but failed to estimate bigeye tuna catch by fish tank. Furthermore, they failed to estimate the proportion of tuna species and proportion of yellowfin tuna by commercial size category by fish tank. In terms, of bigeye tuna by commercial size category by fish tank, there was not enough data for a good comparison. Overall, this shows that depending on the set type and fish typology, crew estimates will tend to better estimate species and fish size which dominates the catch. Most of the oversampled fish wells, catch was fished from FAD sets dominated by small specimens. As stated in Anon (1984) "*small tunas often tend to be misclassified as being skipjack, when they contain significant amount of small yellowfin and small bigeye simply because yellowfin, skipjack and bigeye of less than 3.2 kg tend to be sold at same prices at small sizes*".

Furthermore, the vessel crew (responsible for completing logbook and well-map) was able to estimate total retained tuna catch, total retained skipjack tuna and total retained yellowfin tuna catch and to some extent total retained bigeye tuna catch by trip. However, vessel crew failed to estimate proportion of tuna species and proportion of yellowfin tuna and bigeye tuna by commercial size category by trip. Logbook overestimated skipjack by 13.03%, overestimated bigeye by 30.92% and underestimated yellowfin by 62.38%. Well-map overestimated skipjack by 13.06%, overestimated bigeye by 28.56% and underestimated yellowfin by 59.11%. Vessel crew measured more of the small (-10) yellowfin tuna and bigeye tuna and less of the large (+10) yellowfin tuna and bigeye tuna than unloading. This shows that vessel's crew was unable to break species accurately. This could be due to the way the catch is handled. It has been established in previous literature that logbook and well-maps data at least for large tuna (large yellowfin and large bigeye) are easily identified set by set by all skippers (Fonteneau et al., 2010) however, the data of this study indicates that this is misleading.

The concept of introducing EMS to monitor bycatch is that it allows simultaneous analysis of both the upper and lower deck. However, despite having the capability to produce estimates of total bycatch, EMS is unable to produce accurate estimates for retained bycatch and discards. This is because the dry observers have difficulties to estimate the quantity of specimens that are being removed from the conveyor belt, on the lower deck, to be discarded, from those (presumably smallest one's that are mixed with the bulk of fish) going in fish tanks (Ruiz et al, 2014). Therefore, since the cameras could not show clean/free view of the wells entrances, it was impossible for DOS and SFA to ensure a correct counting of bycatch species dropping into selected wells. Consequently, no comparison could be performed with the oversampling data. EMS, therefore needs to go through system adjustment in order to better monitor retained and discards mainly on the lower deck. The system need more cameras to monitor both bycatch as well as small tunas dropping into fish wells. As stated by Ruiz et al (2016) "*with the right camera placement and enough cameras, both on the main deck and below deck, accurate bycatch estimation is possible. Furthermore, it is possible to identify the fate of the bycatch and in case of release, how is it done. It is, however, important that cameras continue recording images for at least one hour after brailing ends, after catch of target species is in fish wells and the tow boat is on board*". Yet, this will require assistance from the vessel's crew. As reported by Ruiz (2013) "*the success of an EMS program requires that vessels owners and crew understand the importance of standardized catch handling and control points. EMS are designed to be flexible enough to accommodate a variety of catch handling methods, but handling must be consistent and standardized in order to permit the collection of reliable data"*.

Furthermore, two sets of parameters (EU and IOTC) were used in the length-weight relationship equations for converting length measurements into weight for oversampling and regular sampling procedures. From the various comparisons of catch for retained tuna and the comparisons of species and size composition for retained tuna, parameters of IOTC yield better results compared to parameters of EU. The main reason for this could be that EU parameters are very old compared to what is used by IOTC.

The main limitation of the study was that during the seven months' period from May to December 2016, it was not possible to obtain a single well containing free-school sets of any fish category, big or small. The team managed to sample fish wells containing mixed fish and fish wells containing mainly small fish, with the majority sampled from associated-school sets except for one which was sampled from a mix of free and associated-school sets. Another limitation was the lack of skills and experiences by the SFA dry observers in reviewing and analysing the EMS data. Despite having at-sea experiences and attending a one week training from 16th to 20th of May 2016 by a DOS trainer, overall the work they produced was not to the expectations. It was recommended from the start that SFA should identify more than one dry observers to review the video footages of each trip, however, it failed to implement such recommendation. Therefore, it was decided to have DOS replicate the analysis for the eight fish tanks.

5 Conclusion and Recommendations

The main objective of the study was to compare the data collected using EMS to the data collected from oversampling of catches in port from selected fish wells to determine if EMS records can be used to obtain reliable retained tuna catch and retained bycatch estimates on commercial purse seine vessels. The main finding of this study revealed that EMS has the capability to produce reliable catch estimates, however, it needs further adjustment in the configuration of the system in order to yield more precise and accurate catch figures. Results have shown that there were some statistical differences in retained catch estimates between oversampling and EMS by fish tank. The main reason could be poor camera calibration throughout the project and even poor sampling method by dry observers who reviewed and analysed the video footages.

Furthermore, this study has proven that regular port sampling is, at present, the best method for assessing length frequency distributions of tuna species. However, it is being recommended that changes should be made in the EU sampling system, for instance; to increase the subsamples per fish tank. With such an increase scientists, will better monitor fish wells contain mixed typologies, which in turn will also improve estimation of tuna catch. Furthermore, the study had confirmed what have been previously investigated; which is vessel's crew tends to overestimate some species while underestimating others. Therefore, it is necessary to use estimations from port sampling and unloading to correct such information.

There were no discarded tunas reported by SFA dry observers. However, on trip six the scientific observer recorded 0.2 MT of skipjack tuna being discarded. Nevertheless, with no discarded tunas reported by SFA dry observers, it was not possible to perform analysis to verify if EMS could accurately estimate discarded tunas.

Scientific observers were unable to estimate total bycatch per fishing trip. The main reason for this, is the complexity of the fishing operation which makes it difficult for one observer to monitor all fishing activities. They tend to monitor mainly the upper deck as their main duty is to monitor discards.

Two sets of parameters were used for the conversion from length to weight. Results from the concordance analysis and the chi-square test showed that the parameters used by IOTC is more preferred than those used by EU scientists. It is therefore recommended that the fisheries scientist community establish one international standard length-weight relationship equation to improve the tuna catch estimation of tropical tunas.

Finally, the following actions are recommended to improve the performance of EMS and results obtained from data analysis in the future:

- System set-up: The set-up of the cameras on the lower deck shall be redesigned to allow the identification of all specimens that are stored in each fish tank, in particular bycatch.
- System maintenance: The service provider shall make sure to establish protocols to ensure that cameras are properly calibrated throughout the activities of the vessel and avoid any biases that may originate from displacement of the cameras or changes in the calibrating tool.
- Dry observer protocols and supervision: Training and supervision of observers shall be under constant review. Both the service provider and the agency responsible for data analysis shall adopt strict protocols for the review of fishing trips by observers

and regular supervision of their activities, including replication of data analysis by experienced dry observers.

- Minima sample sizes for EMS: More research is required into assessing the minima number of specimens that would be required to sample from each set depending on the levels of precision that will be required to fulfil different management objectives (e.g. catch limits, regular scientific estimates, etc.)
- Length-weight equations: Scientific observers shall collect length-weight samples at-sea on a regular basis, in order to obtain up-to-date length weight relationships for the major tuna and bycatch species and explore for likely changes of condition factor by fishing area, seasonality, or type of fishing set.
- Regular Sampling EU and Seychelles fleet: EU and Seychelles scientists shall consider revising its regular sampling protocols for yellowfin tuna as the current sample size seems to be insufficient. Also, the large difference between the amount of large yellowfin tuna reported in vessel well-maps and logbooks to that obtained from oversampling warrants further investigation. In addition, port sampling shall be extended to monitor all retained bycatch.

Once the above recommendations have been addressed it is recommended to replicate the analysis conducted in this study, as well as conducting all other tests that was not possible to perform at that time (e.g. sampling of fish tanks of only large fish; sampling of retained bycatch and discards, etc.)

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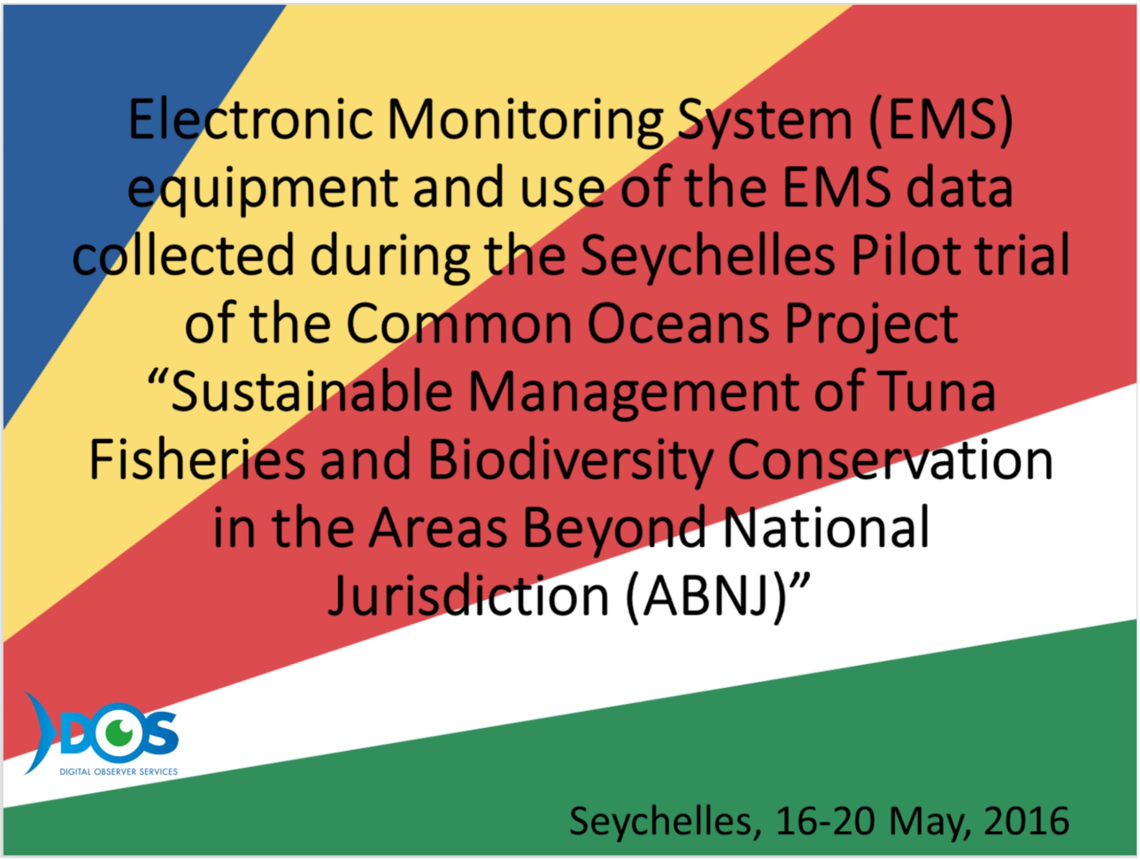
7 Appendices

7.1 Appendix 1: Protocol for Review and Analysis of EMS Data



Video analysis

1. Ask DOS the password of the HDD to be analysed by email:

   dos@digitalobserver.org

2. Once you have the password, make sure the Synology is shut down

3. Install the HDD following the next steps:

   3.1 Open the free bay and install the HDD in the rack

   3.2 Close the bay

   3.3 Switch the Synology on.

Video analysis

3. Conect our control center (PC) to the HDD installed in the Synology opening the **Synology Assistant**.

   This program will help us decript the HDDs and also conect them properly.

4. Once the HDD has been decrypted and mounted, we can start analysing the recordings but to do so, first we have to create a Project opening the SVM in **Wizard Mode**.

Video analysis

Name the Projects this way:

X_nnnnnnnnnnnnnn_yyyymmdd: I_intertuna3_20131203

X: Ocean where the trip took place
- -A for Atlantic Ocean
- -I for Indian Ocean
- -P for Pacific Ocean

nnnnnnnnnnnnnn: complete name of the vessel without spaces, ie. intertuna3

yyyymmdd: date of departure from port ie. 20131203 would be the trip of the vessel that departs the 3rd of December of 2013

Video analysis

4. Start analysis of the project.

    4.1 Open **Map filter**, apply **speed filters** and activate **Show track** to establish the # of sets occurring during the whole trip. The points matching the criteria are marked in **red** and apart from sets include drifts and FAD maneuvers.

    4.2 Use **Report Start** and **Report End** icons to set the start and finish points of the analysis, the moments when the vessel left and arrived.

Video review

4.3 Identify all the **sets,** checking the red track and note the **Fishing start**, **Gear Set**, **Gear Retrieve** and **Fishing End**.

- **Fishing Start** and **Gear Set** when the skiff's cable is released
- Identify the **set** type in the **Gear Set** declaration
  -A: free school tuna
  -O: FAD or any object
  -WS: whale shark
  -M: mammals
- **Retrive Gear** when the rings are up
- **Fishing End** when the skiff's cable is tighten

Video analysis

4.4 Identify all the **FAD activities,** checking the red track and course changes. This allows you to identify:
-**Visited FADs**
-**Collected FADs**
-**Transferred FADs**

FAD deployments are not able to be identified by the speed threshold filter since vessels usually do not slow down their speed for this purpose.

To succeed with the FAD deployment identification, a careful analysis of the video footage is required, especially of those related with FAD making periods.

Video analysis

5. After completing the set and FAD activity identification, proceed with the **catch** and **bycatch** analysis in each one of the identified sets.

   5.1 Speed through the hauling of the net, watching for any bycatch being entangled. Whenever that happens use the **Unspecified Catch Method** declaration prior to the "**Bycatch**" one.

   5.2 When the brailing begins, declare each **brail** making an estimation of how much tuna they have inside.

   5.3 Use the lower deck cameras to identify the **well/s** is/are being used and the **tuna** and **bycatch** species.

   5.4 After all the fish has been hauled, declare the **catch** for each tuna species and size stored per well in the set.

   5.5 During a set analysis, declare **bycatch** species using the "Bycatch" icon, where you can also measure them.

Video review

   5.6 Do not forget to put a **Brail total** icon before the **Fishing End** since it counts the total number of brails during the set which are shown in the Report List.

   5.7 Use **Dirty lens** declaration every time the cameras are not clean.

   5.8 Use **Transhipment** declaration whenever it occurs.

6. Once the analysis is finished, collected data can be imported in 2 different ways:

   - **Inspection Report**: allows to get a PDF file any declaration you want.

   - **EDI file** can be sent to DOS, so we can send you back an Excel file with all the information of the analysed fishing trip.

7.2 Appendix 2: Data Collection Protocols provided by OPAGAC

Pilot Activity to Assist the Implementation of an Electronic Monitoring System on Fishing Vessels Operating in the Republic of Seychelles

Data Collection Protocols

Prepared by Miguel Herrera[1] (OPAGAC)

Introduction

This activity will be executed under the frame of the Common Oceans Sustainable Management of Tuna Fisheries and Biodiversity Conservation in the Areas Beyond National Jurisdiction Project (ABNJ Project), in line with Component 2 of the ABNJ Project Strengthening and Harmonizing Monitoring, Control and Surveillance (MCS) to Address Illegal Unregulated and Unreported Fishing (IUU). In particular Outcome 2.1. Monitoring, Control and Surveillance (MCS) systems, particularly those addressing IUU fishing and related activities are strengthened and harmonized over all five t-RFMOs, as well as with Output 1.1.2 of the project: Increased capacity of ten coastal developing States to comply with t-RFMO member States obligations, through enhanced compliance with IOTC Resolution 11/04.

The implementation of Electronic Monitoring Systems in two purse seiners registered in Seychelles, which is tested through this Pilot, will assist to strengthen the capacity of the Seychelles Fishing Authority to monitor Seychelles flagged and foreign licensed vessels, and prove that e-Monitoring can be used in the Indian Ocean in a transparent, efficient, and cost-effective way and complement human observers.

The Data Collection Protocols that are outlined in this document relate to Component III of the Pilot: Capture, compilation and analysis of e-Monitoring data. This include the type of data that SFA and other parties will need to collect and compile through the Pilot. This information is required to conduct the data analysis specified in Component IV: Data analysis and dissemination of results.

Analysis and storage of e-Monitoring data from the purse seine vessels

The institutions responsible for the implementation of this activity (Component III, Activity 1 of the Project) are the Seychelles Fishing Authority (SFA) and Digital Observer Services (DOS). Activity 1 covers the analysis of e-Monitoring data collected on the two Seychelles flagged purse seiners, Intertuna Tres and Galerna Tres, in which SatLink-DOS has installed e-Monitoring Systems, as required by the Project (Component I).

e-Monitoring Data will be analyzed by two DOS Certified[2] 'dry' observers in Victoria, Seychelles, and the work will be supervised by a SFA staff[3]. In addition, dry observers from DOS will cross-verify e-monitoring data from selected trips in Madrid, Spain, with validation of at least one trip from each SFA dry observer, selected at random.

Dry observers will analyze video images using the software provided by DOS, and complete the required forms. An example of the type of data that will be produced can be found in *Appendix I*. The catches, effort, and other vessel activity data produced from the E-monitoring video images will be compared with the data compiled from other sources, as specified in the following sections.

Compilation of data from other sources

[1] Deputy Manager (Science)
[2] The term Certified refers to dry observers that have attended training by DOS (Project Component II) and have been accredited by DOS upon successful completion of such training
[3] The SFA shall communicate the name of the supervisor to the Project as soon as possible

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Component III, Activity 2 of the Project refers to the compilation of information on catches unloaded/transshipped from purse seiners in Port Victoria (transfer to canning factory or cargo freezer) and oversampling/total enumeration in port of catches from selected fish wells. The SFA will be responsible for the implementation of this activity, which includes:

- Compilation of data completed by the **fishing sector**: This refers to:
    - **Logbook data**: Logbooks are used to record the activities of purse seiners while at-sea, including fishing and non-fishing activities. They are completed by the captain of the ship or the fishing master. Examples of the logbooks used by the SFA can be found in *Appendix II*. The SFA will ensure collection, computerization, validation, and reporting, in electronic format, of logbook data, from all trips made by the two purse seiners under the project.
    - **Fish storage data**: Purse seiners store their catches in fish wells, located in the lower deck (*Figure 1*). Thus, the catches from each set are stored in one or more fish wells. This depends on the size of the well and the catches made on that set. Chief Engineers keep a record of the amount of tuna stored in each well, by set, and species/commercial category. Examples of the well maps used for Intertuna Tres and Galerna Tres can be found in *Appendix III*. The information recorded on well maps is extremely important to the Project. The SFA will ensure collection, computerization, validation, and reporting, in electronic format, of logbook data, from all trips made by the two purse seiners under the project.
    - **Unloading data**: At the end of each trip purse seiners put in to port, where they usually unload the tuna they caught during the trip. Fish may be unloaded through three different channels, with one or more of them used depending on the trip:
        - **Canning factory** (Indian Ocean Tuna (IOT)): The amounts unloaded to IOT are usually recorded in kilograms (?) and broken by species and size category.
        - **Cargo freezer:** Purse seiners may transfer their catches to cargo freezers that will carry them to other destinations for processing. Initially the amounts transshipped are recorded in metric tons (?) and broken by commercial category (?).
        - **Local:** non-market species, which include bycatch and small or damaged species of tuna are usually sold locally or given to the stevedores (local personnel that assist the unloading of the vessels). The rest of the catch, if any, is collected for disposal. It is not clear if the SFA or the fishing boats keep a record of the fish that is sold locally, given or disposed of, although it is very unlikely.

      Unloading data are used to adjust the catches of market species (tropical tunas and albacore) reported in logbooks and well maps. The SFA will ensure collection, computerization, validation, and reporting, in electronic format of canning and transfers to cargo freezer data. Both the SFA and OPAGAC will explore the availability of data on fish unloaded through other channels (local). Examples of the above forms are presented in *Appendix IV*.
- Compilation of data collected by **SFA staff** as part of its regular duties: This includes:
    - **Samples of fish from selected fish wells**, collected by port samplers in port: Seychelles and the EU have coordinated data collection and processing activities in the Indian Ocean, which include sampling of selected fish wells on unloading of purses seiners in Port Victoria, based on agreed sampling protocols. The SFA is responsible for sampling activities in Port Victoria, including selection of fish wells for sampling at the end of each trip and sampling by SFA enumerators. Samples are selected depending on the type of fish in the selected well: if all fish is of large size (length equal or greater than 80 cm) the enumerators take two samples of 100 fish each, at different times during the unloading, classify by species and measure all fish by length. If there is small fish in the well (mixed or not with large fish) the enumerators will do as follows:

- Fish having length 80 cm or greater: Enumerators sample for length and species as many fish as possible from the well;
- Fish having length smaller than 80 cm: Enumerators take two samples, at different times during the unloading, sampling 300 fish and then 200 fish (500 fish in total). Each sample consist on measuring for length (first 30 skipjack tuna and all other species) and counting (remaining skipjack tuna) fish from the selected well, by species.

Sampling data are used in combination with logbook, well map and unloading data to produce final estimates of catches by species and length for the Seychelles purse seine fleet. Examples of the sampling forms used are presented in *Appendix V*.

- **Information on the activities of purse seiners** at-sea, collected by scientific observers: At present all activities of Seychelles flagged purse seiners are covered by scientific observers. However, some companies under OPAGAC are considering a partial phase-out of scientific observers that will be replaced by the Satlink-DOS electronic observer system. This system has undergone independent validation by the Marine Resources Assessment Group (MRAG-UK), and is considered compliant with domestic (Seychelles) and international (RFMO) requirements. OPAGAC will ensure that at least half the trips of Intertuna Tres and Galerna Tres are covered by scientific observers. The SFA is responsible for the implementation of the observer program, which is a voluntary program fully funded by the ship operators. Scientific observers collect information on purse seine activities at-sea which include information on catches, effort, FAD designs and activities, bycatch and liberation of marine fauna. Examples of the forms used by observers can be found in *Appendix VI*.

An example of the output files that will be produced from each dataset is presented in *Appendix VII*. The SFA will transfer all output files to OPAGAC, in electronic format, to OPAGAC, at the end of each trip. Where possible, the SFA shall promote the prompt computerization and reporting of all the data compiled throughout the Project.

Oversampling of catches from selected fish wells

Component III, Activity 2 of the Project covers oversampling of fish wells in port by enumerators. Oversampling is not part of the regular data collection activities conducted on purse seiners. The data collected through oversampling will be used to estimate the species composition of the selected fish wells and how such estimates compare with the catches estimated from other data sources. The SFA will be responsible for the implementation of this activity. The SFA will appoint an Oversampling Team Leader, who will be responsible for the selection of the fish wells to oversample at the end of each trip, selection of the 4 enumerators, and monitoring of sampling activities in port, on board the purse seiners selected. A total of ten fish wells will be oversampled, or about one trip per fishing trip per vessel. The process to select the fish wells to be sampled and procedures that enumerators shall use to sample the selected fish wells are presented in *Appendix VIII*, which also includes the format of the forms to be completed on board by enumerators and data input and reporting formats (Excel worksheets).

The SFA will share all data collected under the Project, as presented in Appendices to this document, with OPAGAC and the University of Alicante. The University of Alicante will coordinate data analysis activities and assist the SFA and OPAGAC to prepare the final reports and documents, as defined in Component IV, Activity 1 of the Project.

Appendix VIII: Oversampling of Fish Wells

Oversampling consists on measuring as many individuals as possible from a sampling unit/population in order to obtain a very accurate and precise estimate of the total number/weight of individuals that make that sampling unit/population.

In the case of purse seiners the sampling unit of choice is the fish well, in which fish from one or more sets may have been stored.

Purpose of oversampling: The purpose of this activity is to assess the accuracy of estimates of catches by species and length frequency distributions following data analysis by dry observers of the video footage obtained from the two purse seiners under the Project, which are equipped with Satlink-DOS Electronic Monitoring Systems.

Approach: Data from oversampling will be used to produce estimates of catch and length frequency distributions by species and length and such estimates will be compared with those produced through analysis of video footage and other sources (logbooks & well maps, scientific observers, regular port sampling, and unloadings).

Methodology: The following procedures will be used to select fish wells for sampling and oversampling of fish from such wells:

- <u>Selection of fish wells</u>: At the end of each trip the oversampling team leader shall collect a copy of the well map from each purse seiner in order to select the well to be sampled. Initially one fish well shall be selected from each trip. The team leader will take into account the following on selection of the fish wells to be sampled:
    - Where possible, ***the well selected shall not contain fish from a set from which the catch has also been stored in other fish well***(s), in particular if loading of the fish wells has occurred simultaneously (i.e. two or more fish wells open at the same time while loading the fish from the set)[4]. This information has to be obtained from the Chief Engineer of the vessel.
    - The ***fish wells selected shall contain different typologies of fish*** as refers to the species and sizes inside them so as at the end of the Project samples from as many typologies as possible can be compared. The objective is that at the end of the Project:
        - There are at least <u>two samples available</u> from the following typologies[5]:
            - Fish wells that contain <u>only large fish</u>
            - Fish wells that contain <u>only small fish</u> or where it represents the large majority of the catch (only some specimens of large fish reported on logbooks, or none)
        - There are at least <u>four samples available</u> from fish wells that contain a <u>mix of fish from various sizes</u>[6].
- <u>Sampling procedure</u>: Oversampling will be conducted by the sampling team leader and four enumerators appointed to the task. The objective is to count all fish in the well that has been selected (disregarding species), and take a sample as large as possible from such fish, to be able to break the catches within the well by gear, species, and size. The sampling procedure is explained below:
    - ***Total enumeration of fish unloaded from the well***: Unloading of fish wells by stevedores is done very fast and therefore it is unlikely that enumerators will have the capacity to count all fish

[4] This is to be able to identify the stream of video footage that relates to the fish in the well selected for oversampling so as the analysis refer to the same fish.

[5] These two refer in general to free-school sets.

[6] These refer in general to associated-schools sets or a mix of free and associated schools. The team leader shall try to select fish wells with various degrees of mix regarding set school type, size, and species.

unloaded from the selected well, eyeball. Thus, monitoring of such fish will be done using a camcorder, to be located near the well selected to ensure that it covers all specimens unloaded from the well. Following recording of the whole unloading of the well, the team leader will coordinate analysis of video images and counting of all fish unloaded from those images. Where possible, fish will be classified by size category, with the numbers of fish having fork length greater and smaller than 80 cm recorded separately. The total number of fish unloaded will be recorded in the Oversampling Form A. The sampling Team Leader will be responsible for ensuring full video monitoring of all fish unloaded from the well and classifying and counting of fish from the images recorded.

- ***Intensive sampling of fish throughout unloading of the selected well***: Enumerators will follow a procedure similar to that used for regular sampling of tunas, with two types of sampling depending on the type of fish stored in the selected well:
    - Only large fish (lengths of all fish 80 cm or greater): Enumerators will classify by species and take length measurements of as many fish as possible throughout unloading of the well selected, with fish selected at random. Samples for length shall consist of at least 300 specimens with fish measured for length over the whole unloading. The fish sampled will be recorded in the Oversampling Form B.
    - Presence of small fish (only fish having length smaller than 80 cm or mix of small and large fish): Sampling will be conducted separately for large and small fish:
        - Large fish (length ≥ 80 cm): If present, as many as possible large specimens, selected at random, will be classified by species and measured for length. The fish sampled will be recorded in the Oversampling Form B, as above.
        - Small fish (length < 80 cm): As many small fish in the well as possible, selected at random, will be classified by species and measured by length. Samples for length shall consist of at least 750 specimens with fish measured for length over the whole unloading. The fish sampled will be recorded in the Oversampling Form C.

  The above sampling applies to yellowfin tuna, skipjack tuna, bigeye tuna, albacore, frigate tuna, bullet tuna, and kawakawa.

  As for non-tuna species, enumerators will try to record all specimens unloaded from the well, recording, where possible, the species and length. The fish sampled will be recorded in the Oversampling Form D.

- Data entry and reporting: All oversampling data will be input as soon as possible in the Excel tables provided to that purpose. Data input and reporting activities will be supervised by the Sampling Team Leader and data sent to OPAGAC as soon as data has been input and verified.

Oversampling Form A: Total Enumeration

This form is used to record the total number of fish unloaded from the well selected for sampling

Sampling	Date	d	d	m	m	y	y	Time Start	h	h	m	m	End	h	h	m	m		
	Date	d	d	m	m	y	y	Time Start	h	h	m	m	End	h	h	m	m		
Name of the boat													Flag	SEYCHELLES					
Date	Trip Start	d	d	m	m	y	y	y	y	Trip End	d	d	m	m	y	y	y	y	
Recording	Date	d	d	m	m	y	y	Time Start	h	h	m	m	End	h	h	m	m		
	Date	d	d	m	m	y	y	Time Start	h	h	m	m	End	h	h	m	m		
Name of samplers																			
Fish Well Sampled		Type of fish	Large		Small		Mix												

Total number of fish unloaded

Tuna Large (FL≥ 80 cm)				Small (FL<80cm)	
Oceaninc Whitetip shark		Silky shark		Other sharks	
Pelagic Stingray		Mantas		Other rays & skates	
Raimbow runner		Triggerfish		Dolphinfish	
Wahoo		Barracuda		Other finfish	
Billfish		Turtles			

Other (specify)

Species/Group	Number

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Oversampling Form B: Large Tuna Form

This Form is used to record the lengths of large specimens of yellowfin tuna (YFT), bigeye tuna (BET), and albacore (ALB)

Name of the boat											Flag	SEYCHELLES						
Date	Trip Start	d	d	m	m	y	y	y	y	Trip End	d	d	m	m	y	y	y	y
Name of sampler(s)											# Tuna Sampled							

Oversampling Large Tuna (≥80 cm)

FL (cm)	*species*	Total	FL (cm)	*species*	Total	FL (cm)	*species*	Total
0			0			0		
1			1			1		
2			2			2		
3			3			3		
4			4			4		
5			5			5		
6			6			6		
7			7			7		
8			8			8		
9			9			9		
0			0			0		
1			1			1		
2			2			2		
3			3			3		
4			4			4		
5			5			5		
6			6			6		
7			7			7		
8			8			8		
9			9			9		
0			0			0		
1			1			1		
2			2			2		
3			3			3		
4			4			4		
5			5			5		
6			6			6		
7			7			7		
8			8			8		
9			9			9		
	Total			Total			Total	

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Oversampling Form C: Small Tuna Form

This Form is used to record the lengths of small specimens of YFT, BET & SKJ and specimens of FRI, BLT & KAW

Name of the boat											Flag	SEYCHELLES						
Date	Trip Start	d	d	m	m	y	y	y	y	Trip End	d	d	m	m	y	y	y	y
Name of sampler(s)											# Tuna Sampled							

Oversampling Small Tuna (<80 cm)

FL (cm)	species	Total	FL (cm)	species	Total	FL (cm)	species	Total
0			0			0		
1			1			1		
2			2			2		
3			3			3		
4			4			4		
5			5			5		
6			6			6		
7			7			7		
8			8			8		
9			9			9		
0			0			0		
1			1			1		
2			2			2		
3			3			3		
4			4			4		
5			5			5		
6			6			6		
7			7			7		
8			8			8		
9			9			9		
0			0			0		
1			1			1		
2			2			2		
3			3			3		
4			4			4		
5			5			5		
6			6			6		
7			7			7		
8			8			8		
9			9			9		
	Total			Total			Total	

Oversampling Form D: Non-Tuna Form

This Form is used to record the lengths of non-tuna species, in particular species of sharks and finfish

Name of the boat		Flag	SEYCHELLES
Date	Trip Start: d d m m y y y y	Trip End: d d m m y y y y	
Name of sampler(s)		# Non-tuna Sampled	

Oversampling Non-Tuna

FL (cm)	species	Total	FL (cm)	species	Total	FL (cm)	species	Total
0			0			0		
1			1			1		
2			2			2		
3			3			3		
4			4			4		
5			5			5		
6			6			6		
7			7			7		
8			8			8		
9			9			9		
0			0			0		
1			1			1		
2			2			2		
3			3			3		
4			4			4		
5			5			5		
6			6			6		
7			7			7		
8			8			8		
9			9			9		
0			0			0		
1			1			1		
2			2			2		
3			3			3		
4			4			4		
5			5			5		
6			6			6		
7			7			7		
8			8			8		
9			9			9		
	Total			Total			Total	

7.3 Comparison of Catch for Retained Tuna

Comparison between DOS EMS Sampling one and DOS EMS Sampling two

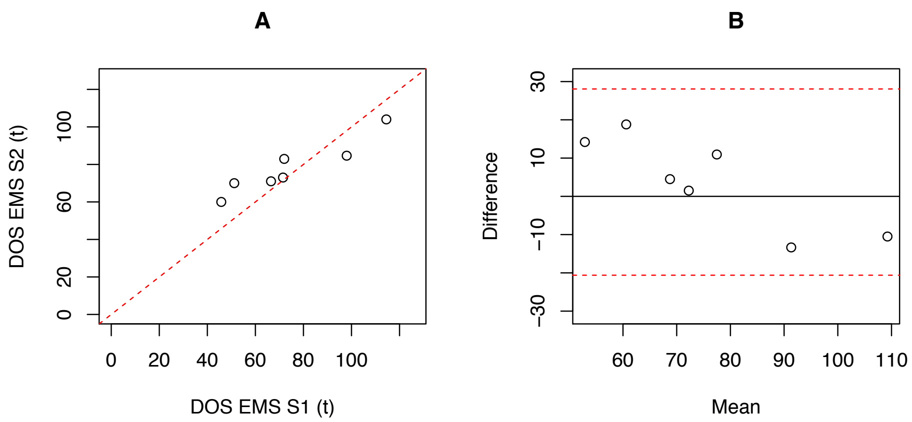


Figure 49: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by fish tank for DOS EMS sampling one (S1) and DOS EMS sampling two (S2) procedures.

Table 70: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by fish tank for DOS EMS sampling one (S1) and DOS EMS sampling two (S2) procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.799	0.544	0.919
ICC	0.823	0.337	0.967
B&A	-3.727	-28.065	20.611

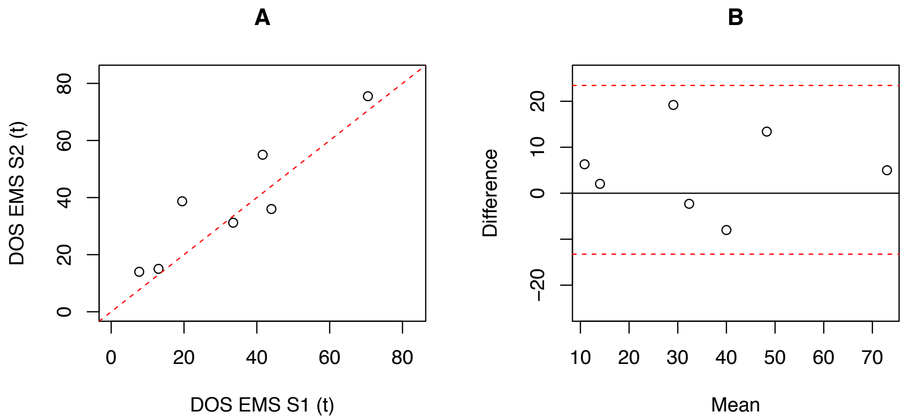


Figure 50: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by fish tank for DOS EMS sampling one (S1) and DOS EMS sampling two (S2) procedures.

Table 71: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by fish tank for DOS EMS sampling one (S1) and DOS EMS sampling two (S2) procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.883	0.497	0.977
ICC	0.897	0.565	0.981
B&A	-5.091	-23.438	13.255

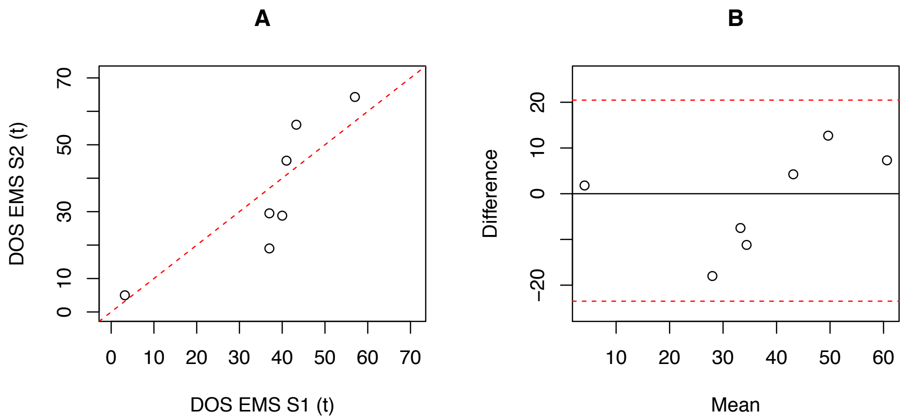


Figure 51: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by fish tank for DOS EMS sampling one (S1) and DOS EMS sampling two (S2) procedures.

Table 72: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by fish tank for DOS EMS sampling one (S1) and DOS EMS sampling two (S2) procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.826	0.366	0.961
ICC	0.848	0.408	0.972
B&A	1.521	-20.469	23.512

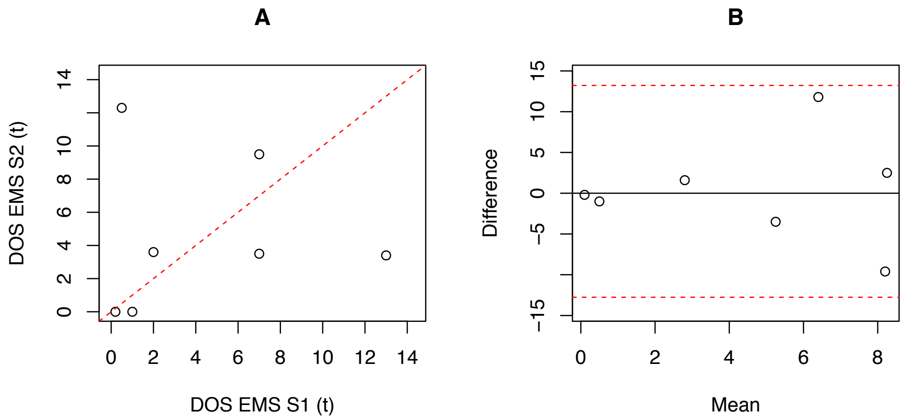


Figure 52: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by fish tank for DOS EMS sampling one (S1) and DOS EMS sampling two (S2) procedures.

Table 73: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by fish tank for DOS EMS sampling one (S1) and DOS EMS sampling two (S2) procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.052	-0.677	0.729
ICC	0.127	-0.597	0.761
B&A	-0.229	-13.219	12.762

Comparison between Oversampling EU and Oversampling IOTC with DOS EMS Sampling two

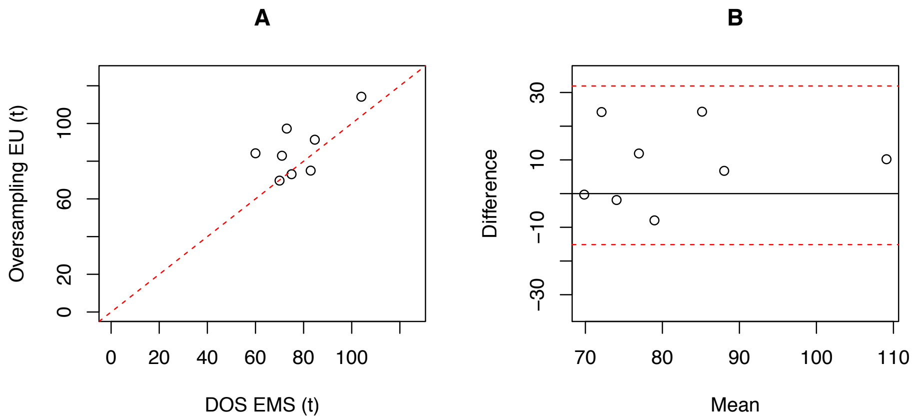


Figure 53: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by fish tank for Oversampling EU and DOS EMS S2 procedures.

Table 74: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by fish tank for Oversampling EU and DOS EMS S2 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.535	-0.070	0.852
ICC	0.540	-0.150	0.885
B&A	8.401	-15.135	31.938

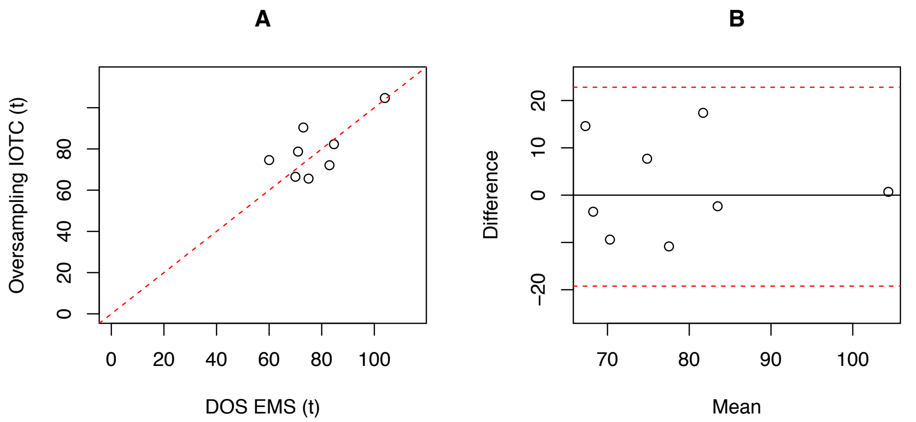


Figure 54: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by fish tank for Oversampling IOTC and DOS EMS S2 procedures.

Table 75: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by fish tank for Oversampling IOTC and DOS EMS S2 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.673	0.023	0.923
ICC	0.706	0.124	0.932
B&A	1.789	-19.238	22.816

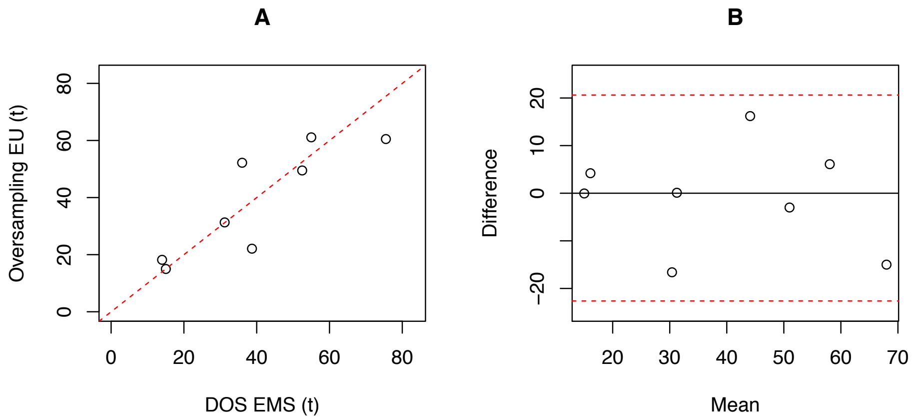


Figure 55: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by fish tank for Oversampling EU and DOS EMS S2 procedures.

Table 76: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by fish tank for Oversampling EU and DOS EMS S2 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.853	0.444	0.968
ICC	0.870	0.522	0.972
B&A	-1.006	-22.636	20.624

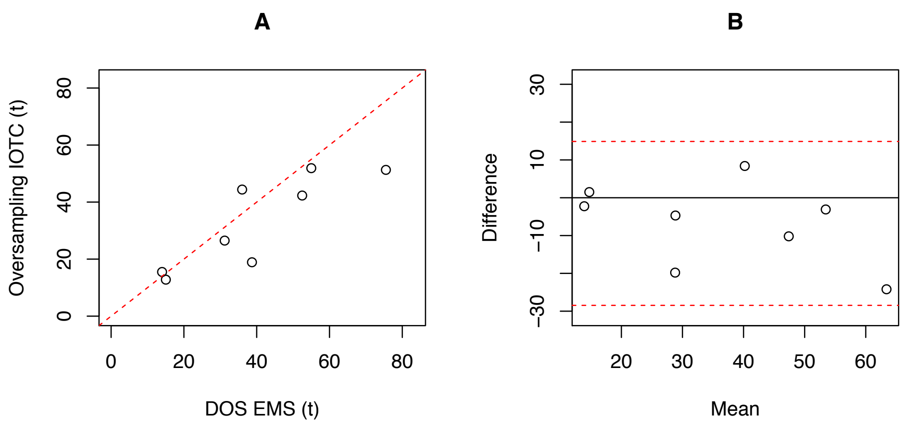


Figure 56: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by fish tank for Oversampling IOTC and DOS EMS S2 procedures.

Table 77: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by fish tank for Oversampling IOTC and DOS EMS S2 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.774	0.329	0.938
ICC	0.792	0.311	0.954
B&A	-6.793	-28.467	14.882

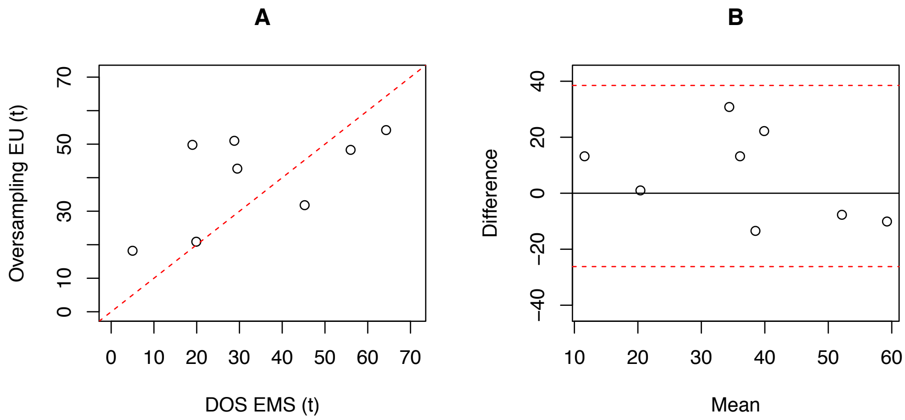


Figure 57: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by fish tank for Oversampling EU and DOS EMS S2 procedures.

Table 78: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by fish tank for Oversampling EU and DOS EMS S2 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.530	-0.100	0.857
ICC	0.562	-0.120	0.892
B&A	6.144	-26.204	38.492

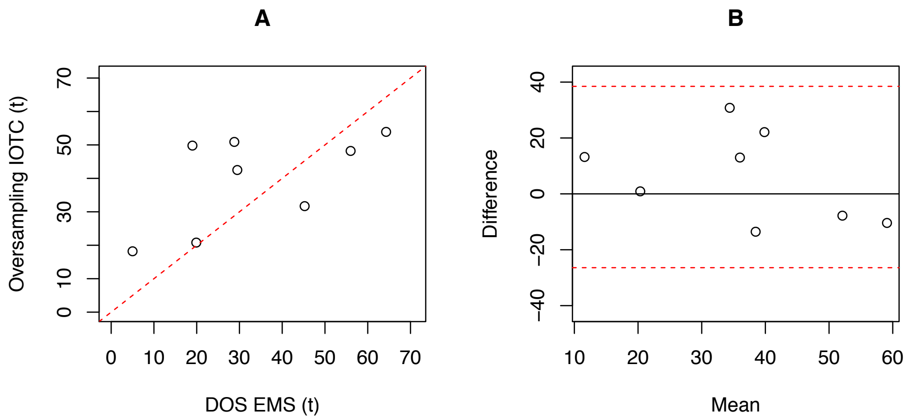


Figure 58: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by fish tank for Oversampling IOTC and DOS EMS S2 procedures.

Table 79: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by fish tank for Oversampling IOTC and DOS EMS S2 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.528	-0.103	0.856
ICC	0.560	-0.122	0.891
B&A	6.031	-26.418	38.481

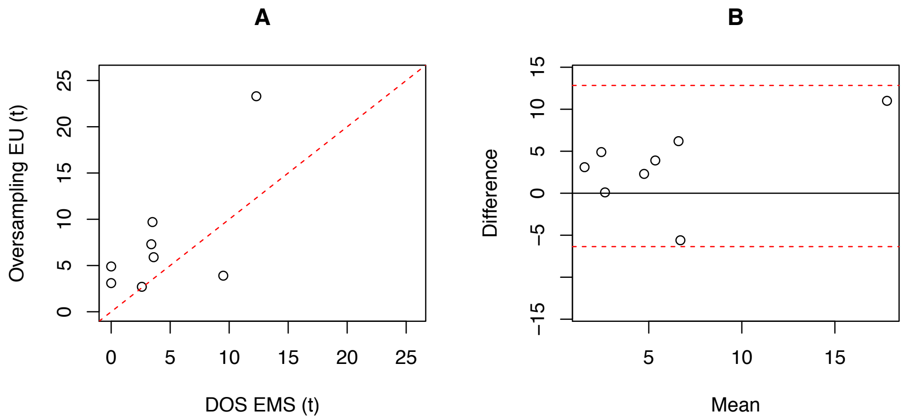


Figure 59: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by fish tank for Oversampling EU and DOS EMS S2 procedures.

Table 80: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by fish tank for Oversampling EU and DOS EMS S2 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.543	0.009	0.836
ICC	0.552	-0.133	0.889
B&A	3.238	-6.357	12.832

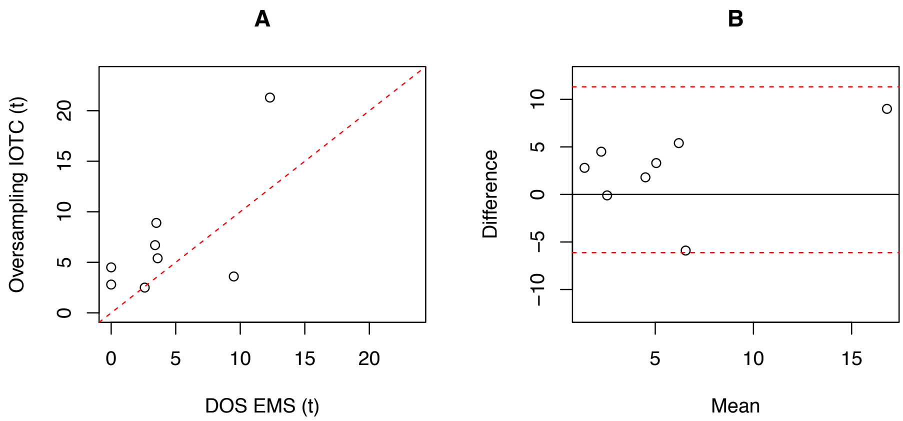


Figure 60: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by fish tank for Oversampling IOTC and DOS EMS S2 procedures.

Table 81: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by fish tank for Oversampling IOTC and DOS EMS S2 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.587	0.023	0.868
ICC	0.605	-0.054	0.904
B&A	2.6	-6.122	11.322

Comparison between Oversampling EU and Oversampling IOTC with SFA EMS

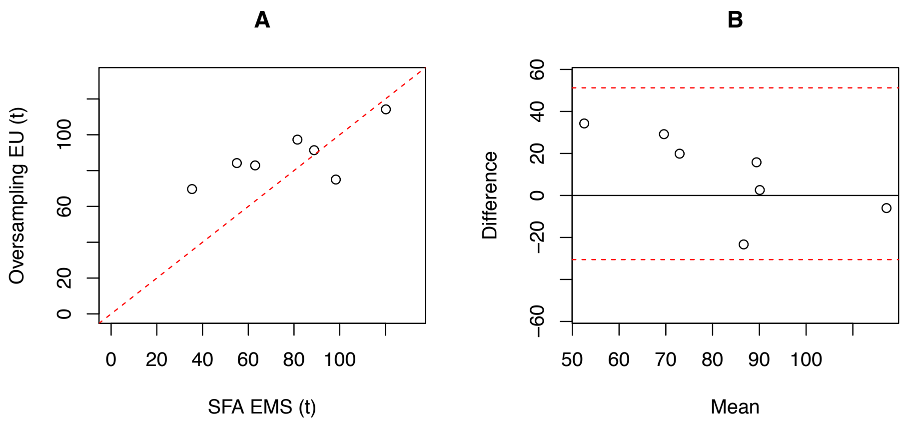


Figure 61: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by fish tank for Oversampling EU and SFA EMS procedures.

Table 82: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by fish tank for Oversampling EU and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.532	0.005	0.828
ICC	0.561	-0.181	0.906
B&A	10.357	-30.545	51.260

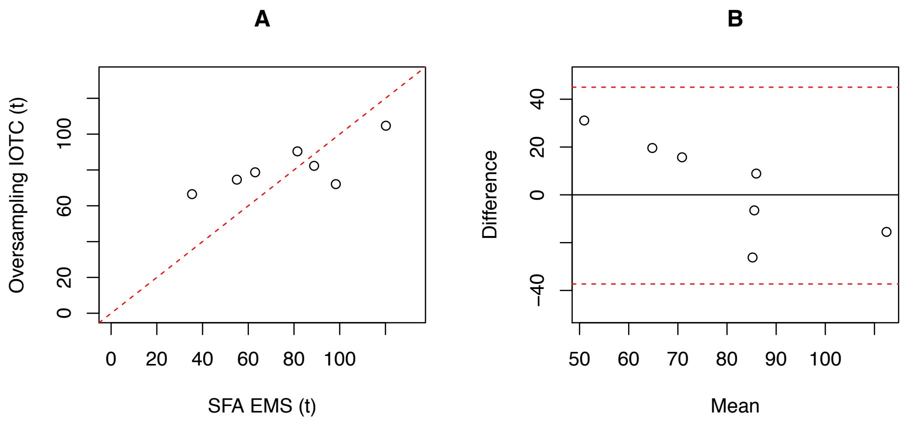


Figure 62: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by fish tank for Oversampling IOTC and SFA EMS procedures.

Table 83: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by fish tank for Oversampling IOTC and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.558	0.109	0.817
ICC	0.605	-0.115	0.917
B&A	3.871	-37.288	45.030

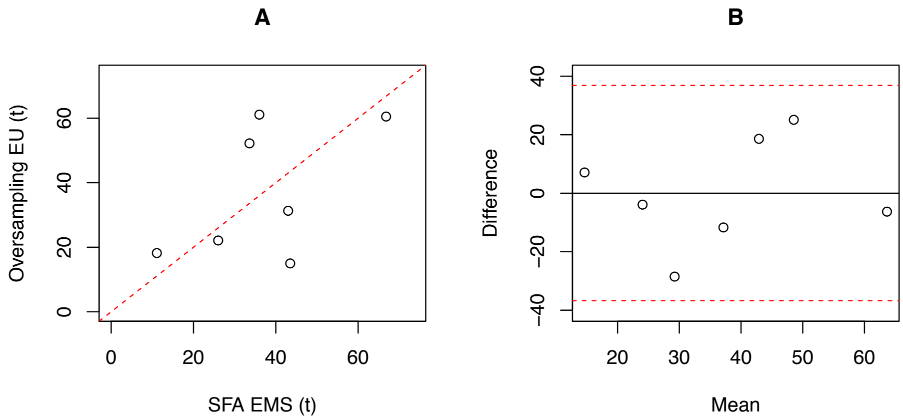


Figure 63: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by fish tank for Oversampling EU and SFA EMS procedures.

Table 84: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by fish tank for Oversampling EU and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.519	-0.277	0.893
ICC	0.573	-0.162	0.909
B&A	0.056	-36.741	36.852

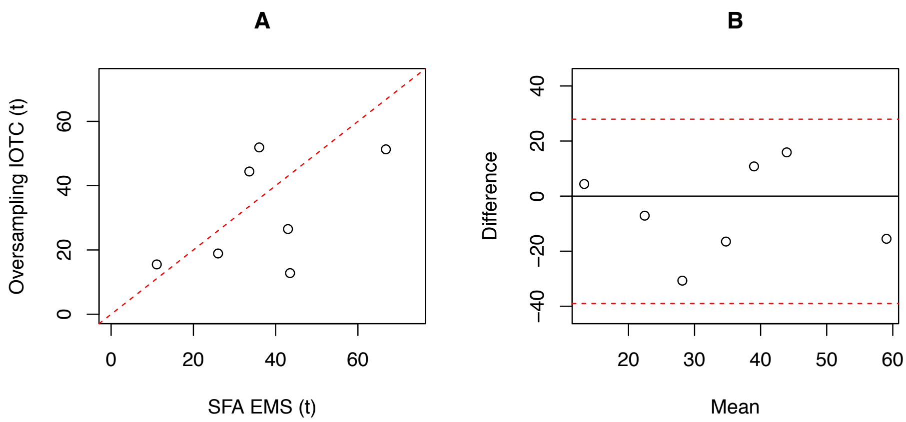


Figure 64: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by fish tank for Oversampling IOTC and SFA EMS procedures.

Table 85: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by fish tank for Oversampling IOTC and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.495	-0.281	0.880
ICC	0.537	-0.213	0.900
B&A	-5.529	-38.998	27.940

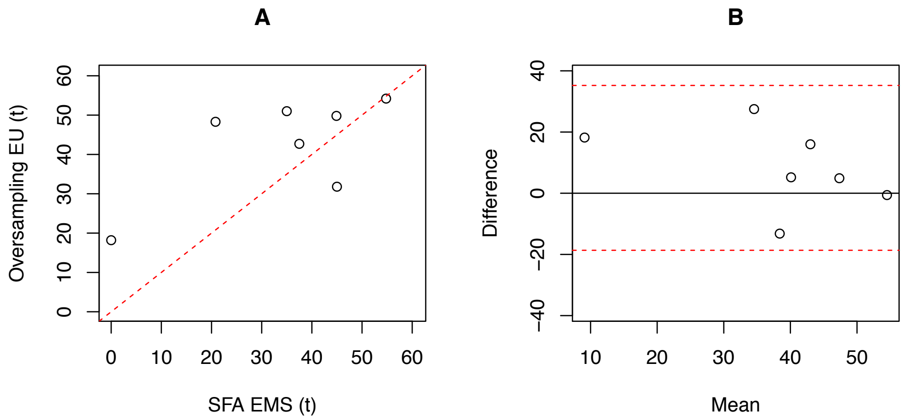


Figure 65: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by fish tank for Oversampling EU and SFA EMS procedures.

Table 86: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by fish tank for Oversampling EU and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.551	-0.082	0.867
ICC	0.572	-0.164	0.909
B&A	8.286	-18.653	35.225

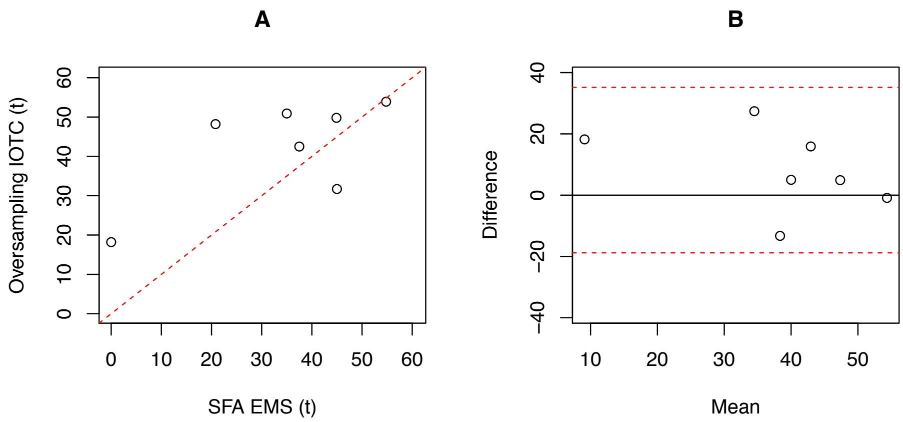


Figure 66: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by fish tank for Oversampling IOTC and SFA EMS procedures.

Table 87: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by fish tank for Oversampling IOTC and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.551	-0.084	0.867
ICC	0.572	-0.164	0.909
B&A	8.171	-18.836	35.179

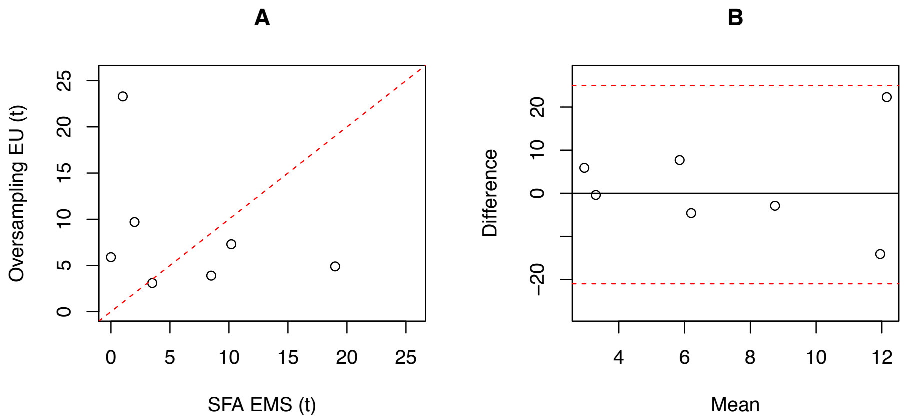


Figure 67: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by fish tank for Oversampling EU and SFA EMS procedures.

Table 88: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by fish tank for Oversampling EU and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	-0.379	-0.848	0.424
ICC	-0.345	-0.826	0.470
B&A	1.986	-20.997	24.969

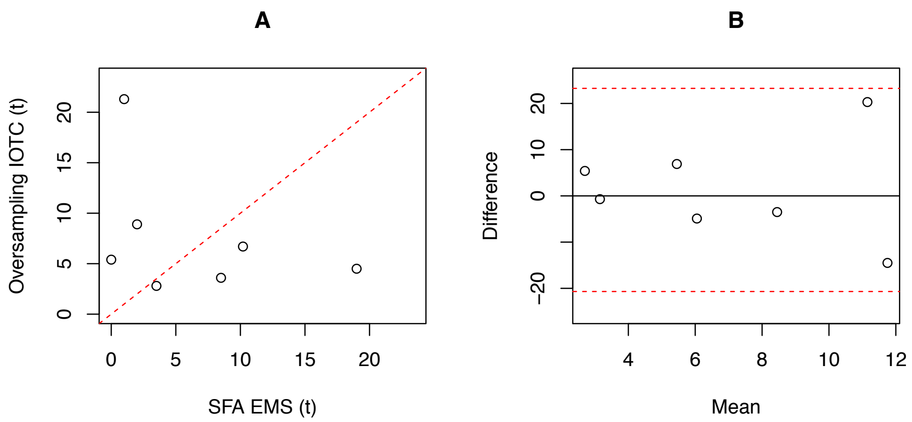


Figure 68: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by fish tank for Oversampling IOTC and SFA EMS procedures.

Table 89: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by fish tank for Oversampling IOTC and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	-0.387	-0.854	0.426
ICC	-0.335	-0.823	0.479
B&A	1.286	-20.688	23.260

Comparison between Oversampling EU and Oversampling IOTC with Scientific Observer Programme

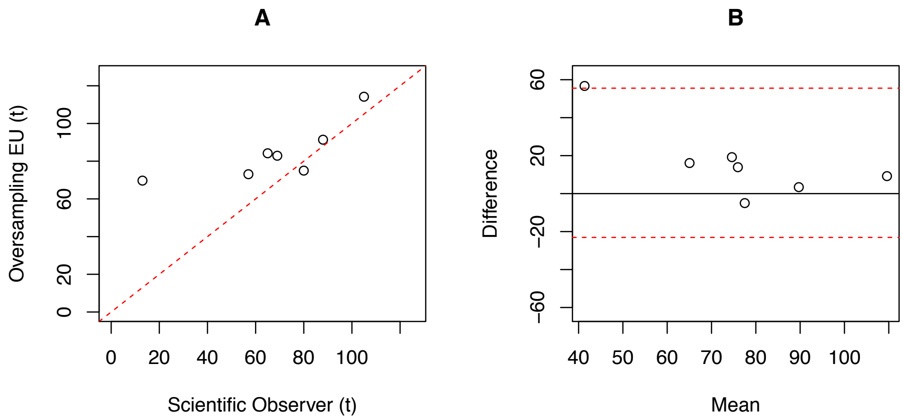


Figure 69: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by fish tank for Oversampling EU and Scientific Observer programme procedures.

Table 90: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by fish tank for Oversampling EU and Scientific Observer programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.498	0.019	0.791
ICC	0.496	-0.266	0.888
B&A	16.214	-23.087	55.515

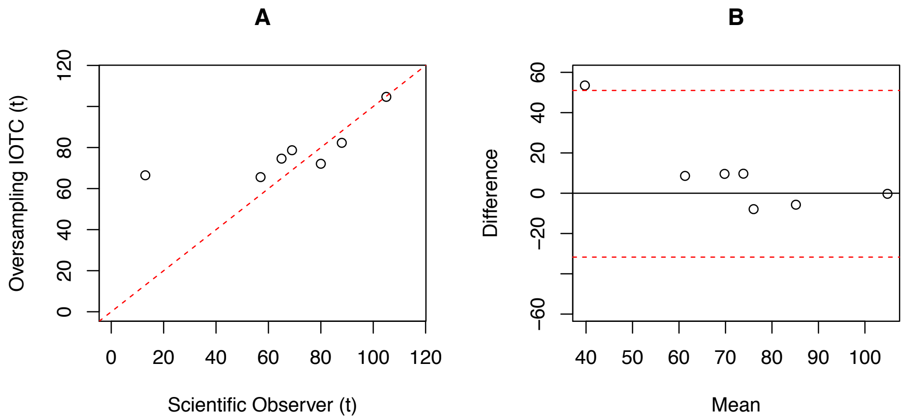


Figure 70: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by fish tank for Oversampling IOTC and Scientific Observer programme procedures.

Table 91: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by fish tank for Oversampling IOTC and Scientific Observer programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.526	0.064	0.802
ICC	0.557	-0.185	0.905
B&A	9.643	-31.722	51.008

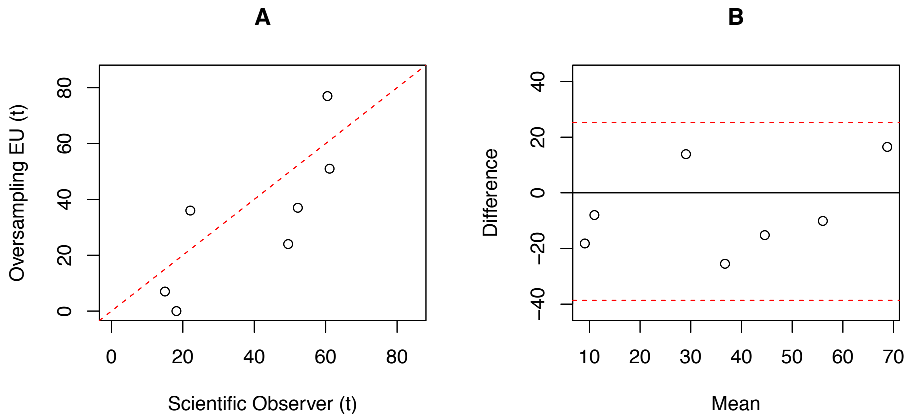


Figure 71: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by fish tank for Oversampling EU and Scientific Observer programme procedures.

Table 92: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by fish tank for Oversampling EU and Scientific Observer programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.735	0.152	0.939
ICC	0.763	0.186	0.954
B&A	-6.656	-38.632	25.321

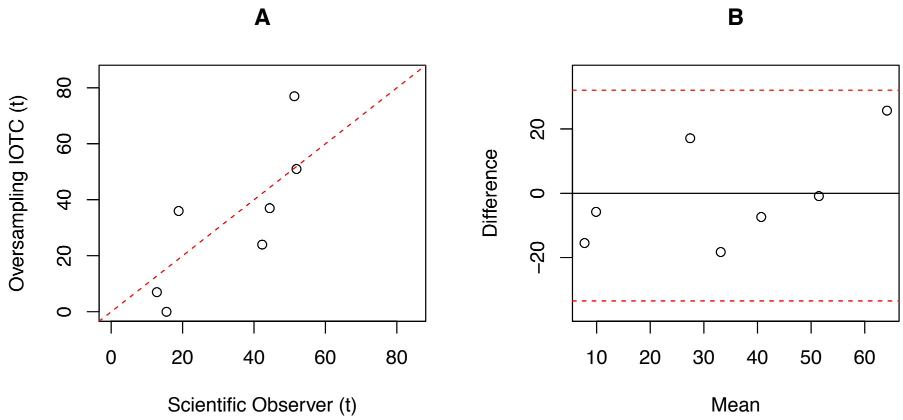


Figure 72: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by fish tank for Oversampling IOTC and Scientific Observer programme procedures.

Table 93: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by fish tank for Oversampling IOTC and Scientific Observer programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.728	0.201	0.928
ICC	0.762	0.183	0.954
B&A	-0.729	-33.526	32.069

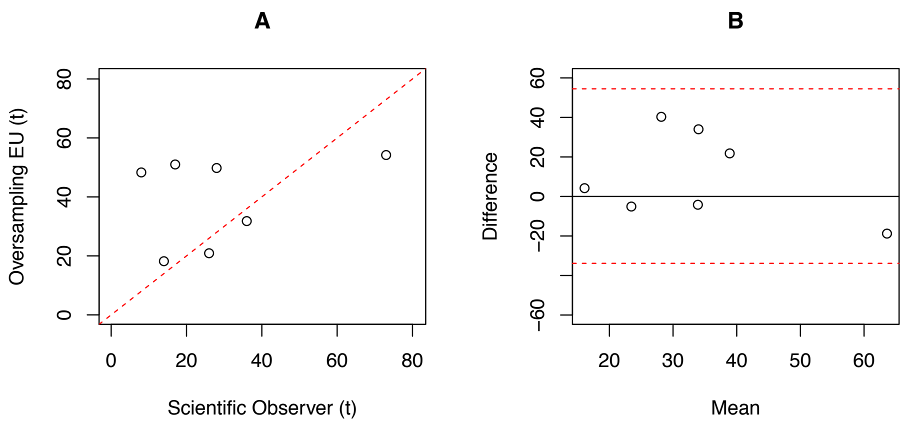


Figure 73: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by fish tank for Oversampling EU and Scientific Observer programme procedures.

Table 94: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by fish tank for Oversampling EU and Scientific Observer programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.257	-0.414	0.747
ICC	0.270	-0.493	0.816
B&A	10.314	-33.847	54.476

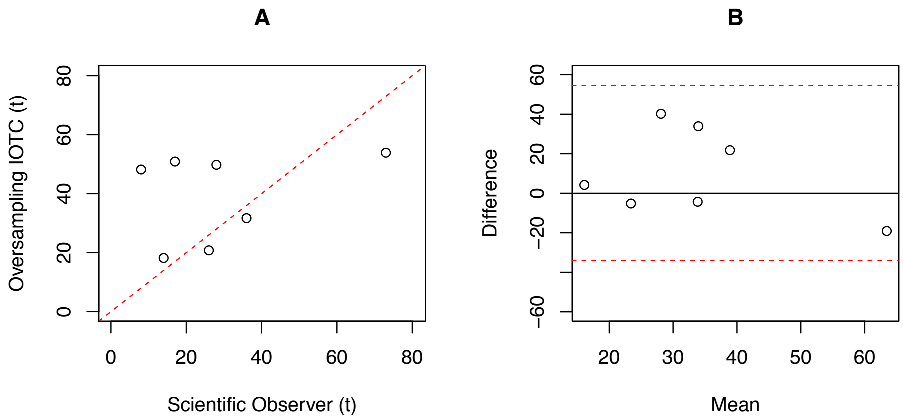


Figure 74: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by fish tank for Oversampling IOTC and Scientific Observer programme procedures.

Table 95: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by fish tank for Oversampling IOTC and Scientific Observer programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.254	-0.418	0.746
ICC	0.267	-0.495	0.816
B&A	10.214	-34.044	54.472

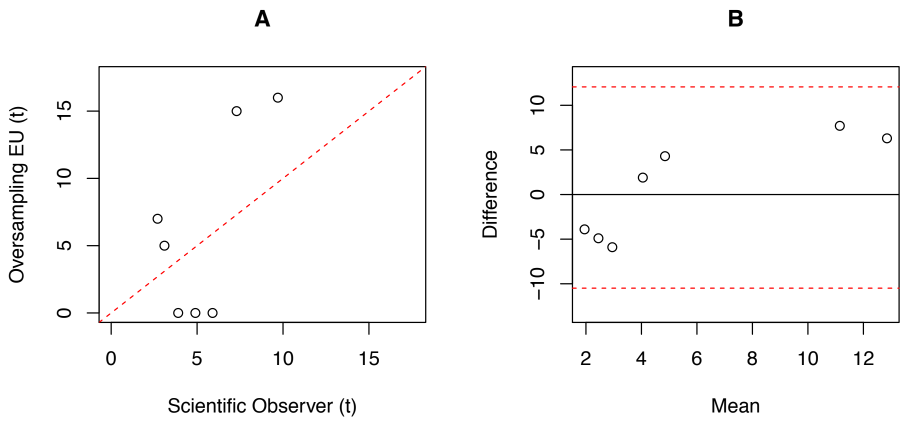


Figure 75: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by fish tank for Oversampling EU and Scientific Observer programme procedures.

Table 96: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by fish tank for Oversampling EU and Scientific Observer programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.413	-0.021	0.716
ICC	0.472	-0.295	0.881
B&A	0.786	-10.492	12.064

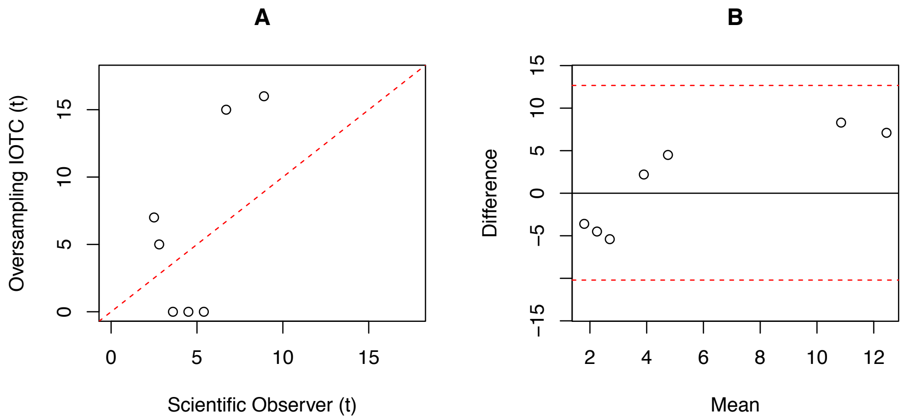


Figure 76: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by fish tank for Oversampling IOTC and Scientific Observer programme procedures.

Table 97: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by fish tank for Oversampling IOTC and Scientific Observer programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.379	-0.025	0.676
ICC	0.434	-0.338	0.870
B&A	1.229	-10.208	12.665

Comparisons between Well-map and DOS EMS Sampling one

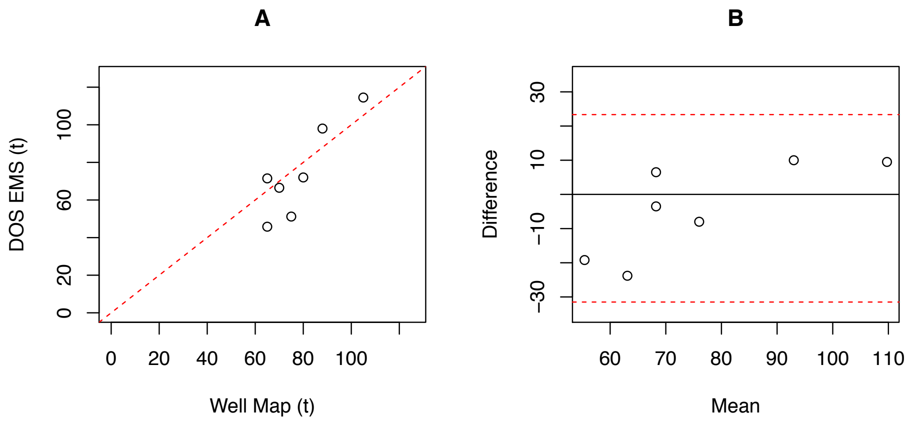


Figure 77: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by fish tank for Well-map and DOS EMS S1 procedures.

Table 98: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by fish tank for Well-map and DOS EMS S1 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.749	0.367	0.915
ICC	0.778	0.221	0.957
B&A	-4.071	-31.492	23.349

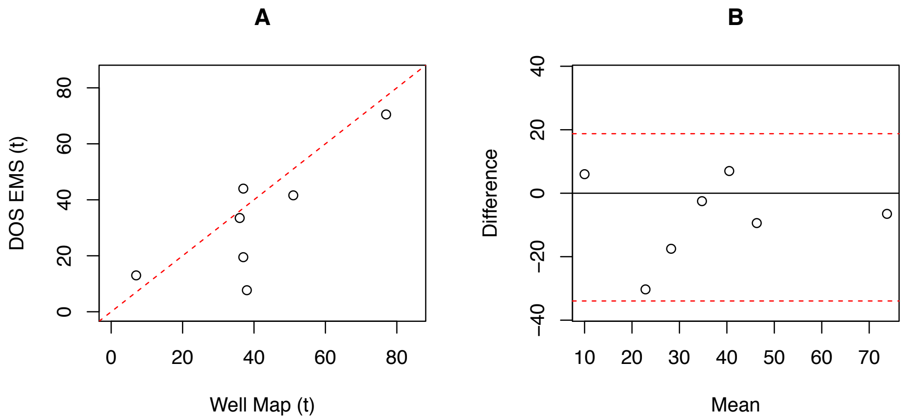


Figure 78: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by fish tank for Well-map and DOS EMS S1 procedures.

Table 99: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by fish tank for Well-map and DOS EMS S1 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.753	0.161	0.946
ICC	0.776	0.216	0.957
B&A	-7.6	-33.955	18.755

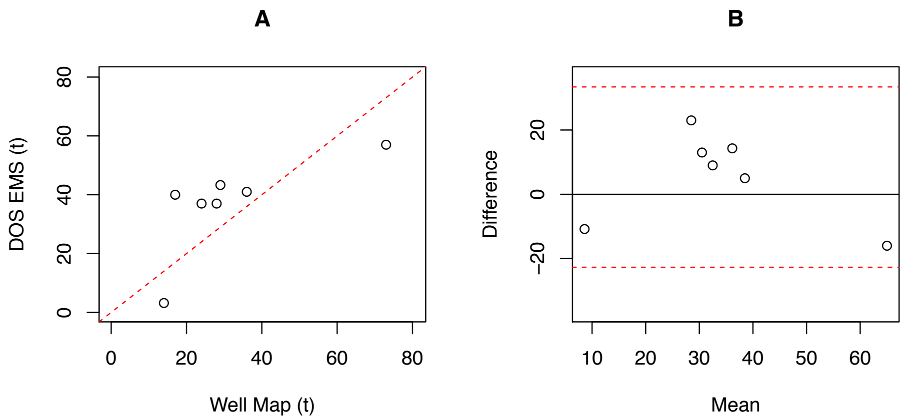


Figure 79: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by fish tank for Well-map and DOS EMS S1 procedures.

Table 100: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by fish tank for Well-map and DOS EMS S1 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.667	-0.009	0.924
ICC	0.700	0.050	0.940
B&A	5.357	-22.693	33.408

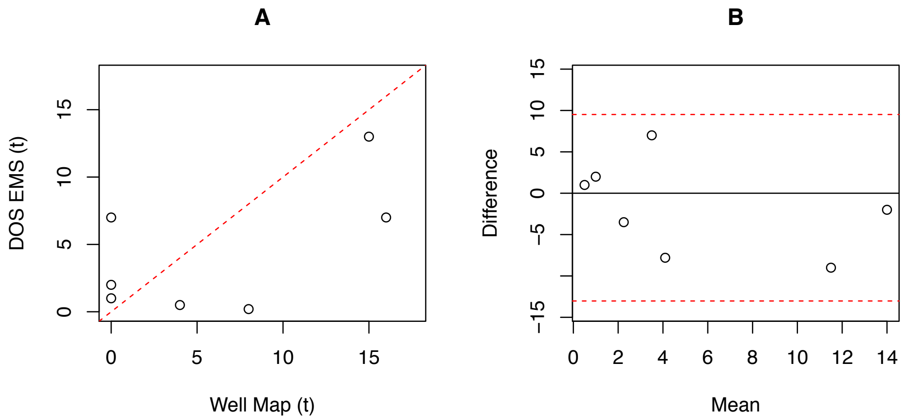


Figure 80: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by fish tank for Well-map and DOS EMS S1 procedures.

Table 101: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by fish tank for Well-map and DOS EMS S1 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.535	-0.159	0.875
ICC	0.577	-0.157	0.910
B&A	-1.757	-13.026	9.512

Comparison between Well-map and DOS EMS Sampling two

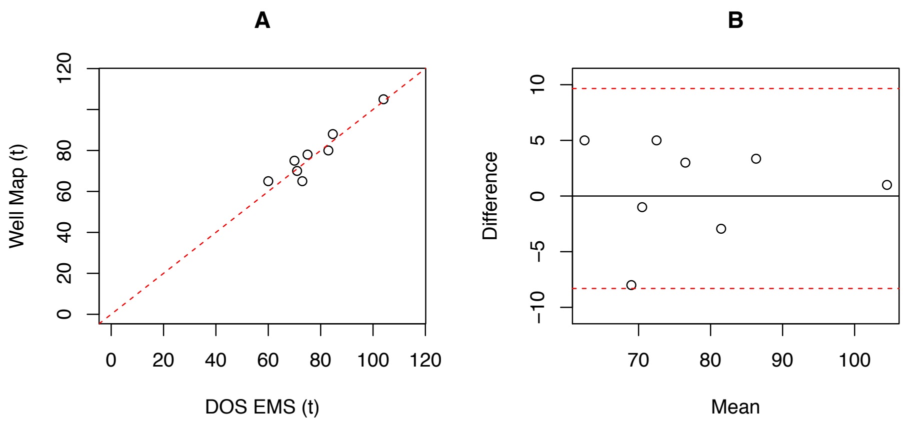


Figure 81: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by fish tank for Well-map and DOS EMS S2 procedures.

Table 102: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by fish tank for Well-map and DOS EMS S2 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.941	0.739	0.988
ICC	0.948	0.785	0.989
B&A	0.676	-8.307	9.659

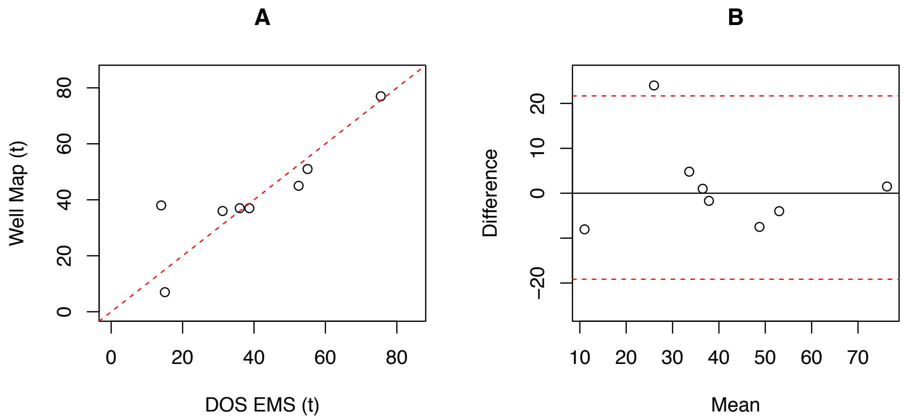


Figure 82: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by fish tank for Well-map and DOS EMS S2 procedures.

Table 103: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by fish tank for Well-map and DOS EMS S2 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.869	0.493	0.972
ICC	0.885	0.566	0.975
B&A	1.258	-19.158	21.673

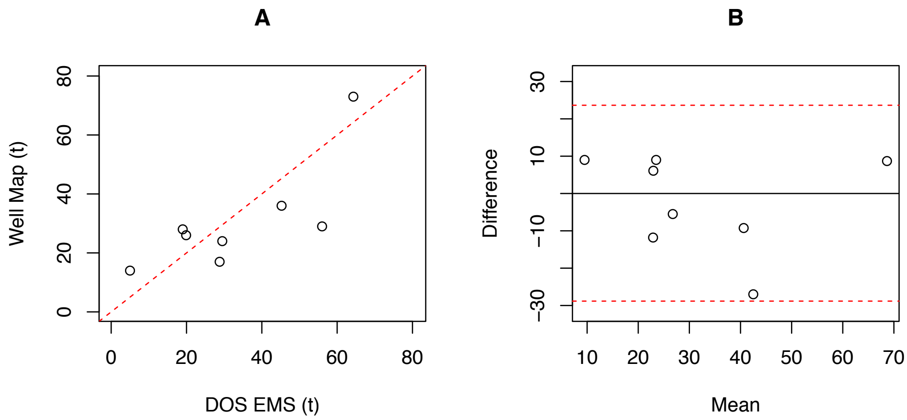


Figure 83: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by fish tank for Well-map and DOS EMS S2 procedures.

Table 104: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by fish tank for Well-map and DOS EMS S2 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.760	0.209	0.945
ICC	0.786	0.296	0.952
B&A	-2.594	-28.836	23.6483

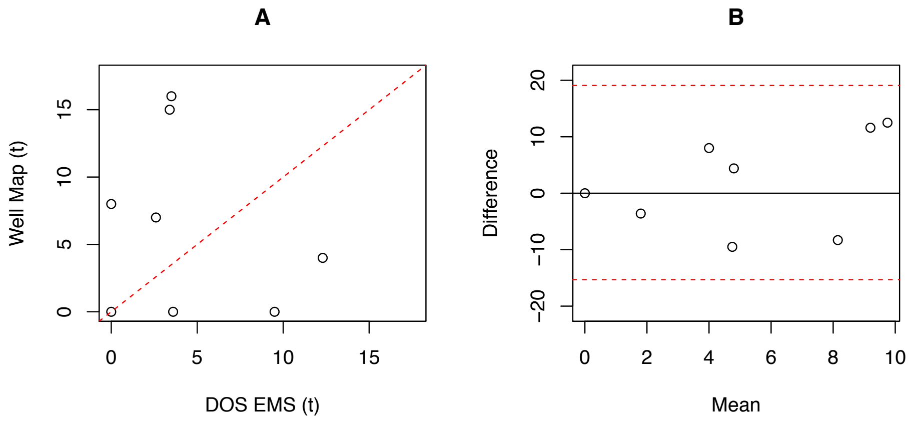


Figure 84: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by fish tank for Well-map and DOS EMS S2 procedures.

Table 105: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by fish tank for Well-map and DOS EMS S2 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	-0.191	-0.710	0.463
ICC	-0.165	-0.727	0.557
B&A	1.888	-15.313	19.088

Comparison between Well-map and SFA EMS

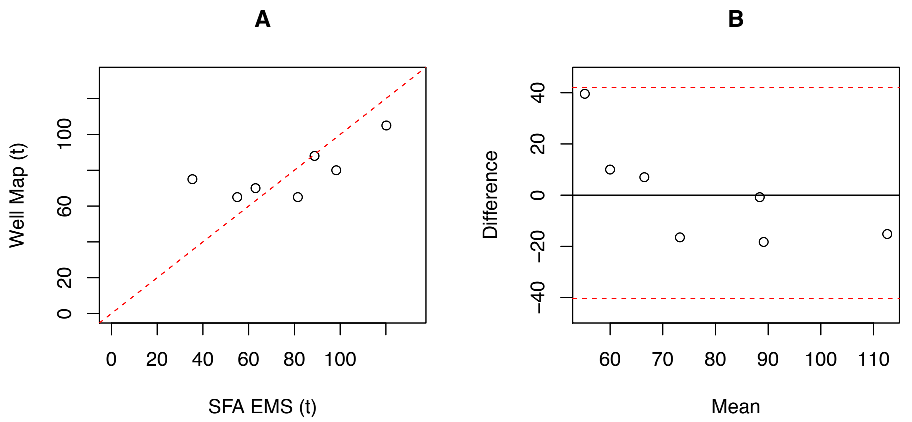


Figure 85: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by fish tank for Well-map and SFA EMS procedures.

Table 106: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by fish tank for Well-map and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.583	0.071	0.852
ICC	0.632	-0.072	0.924
B&A	0.829	-40.412	42.069

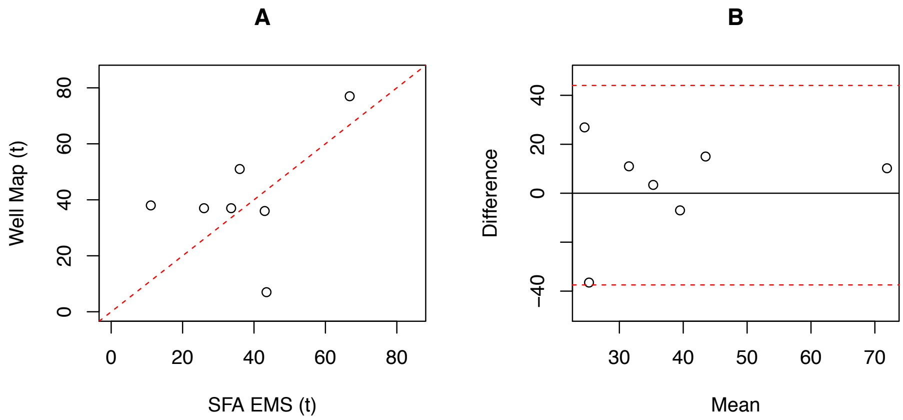


Figure 86: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by fish tank for Well-map and SFA EMS procedures.

Table 107: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by fish tank for Well-map and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.425	-0.371	0.861
ICC	0.481	-0.284	0.884
B&A	3.286	-37.465	44.036

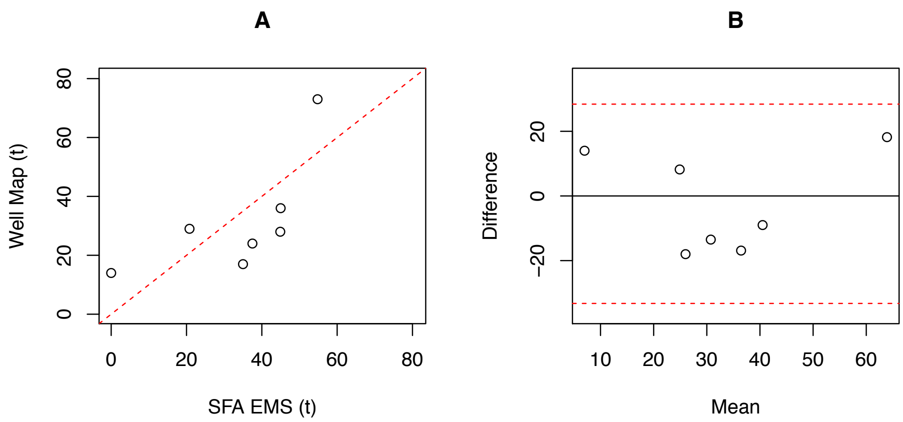


Figure 87: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by fish tank for Well-map and SFA EMS procedures.

Table 108: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by fish tank for Well-map and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.666	-0.062	0.931
ICC	0.705	0.061	0.941
B&A	-2.429	-33.262	28.405

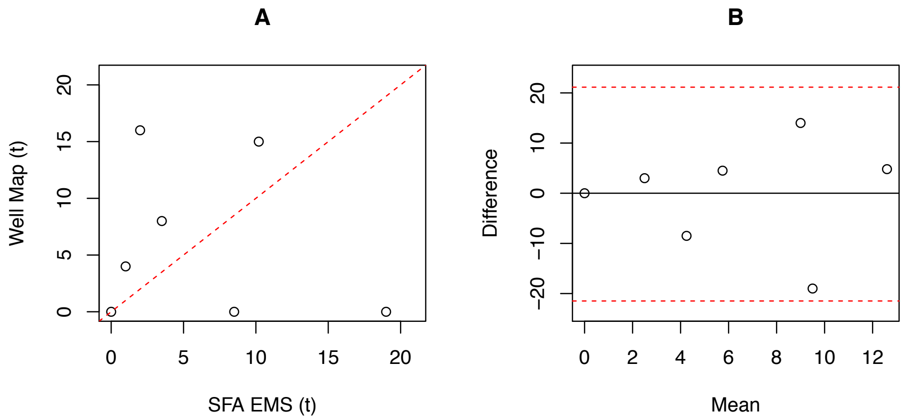


Figure 88: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by fish tank for Well-map and SFA EMS procedures.

Table 109: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by fish tank for Well-map and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	-0.190	-0.789	0.593
ICC	-0.115	-0.732	0.637
B&A	-0.171	-21.484	21.141

Comparison between Well-map and Scientific Observer Programme

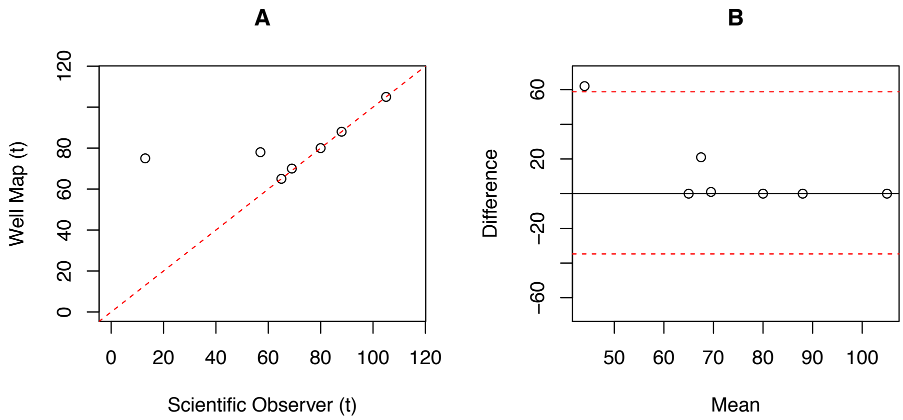


Figure 89: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by fish tank for Well-map and Scientific Observer programme procedures.

Table 110: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by fish tank for Well-map and Scientific Observer programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.398	-0.115	0.743
ICC	0.418	-0.355	0.865
B&A	12	-34.748	58.748

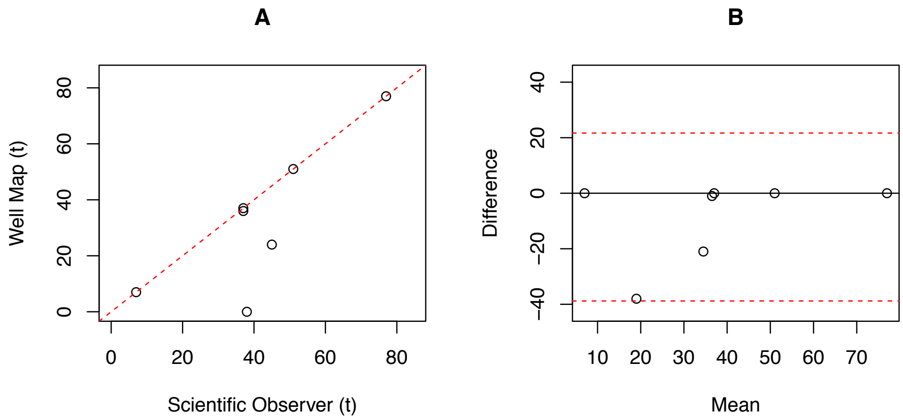


Figure 90: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by fish tank for Well-map and Scientific Observer programme procedures.

Table 111: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by fish tank for Well-map and Scientific Observer programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.740	0.179	0.938
ICC	0.764	0.188	0.954
B&A	-8.571	-38.812	21.669

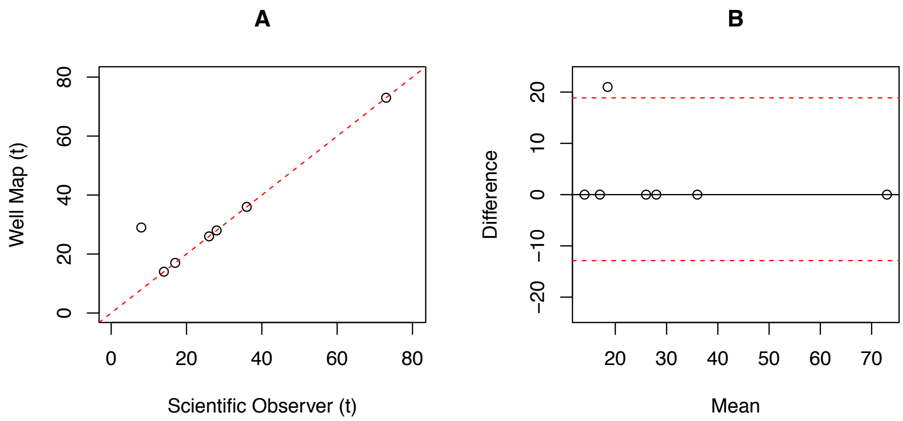


Figure 91: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by fish tank for Well-map and Scientific Observer programme procedures.

Table 112: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by fish tank for Well-map and Scientific Observer programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.915	0.615	0.984
ICC	0.926	0.672	0.987
B&A	3	-12.875	18.875

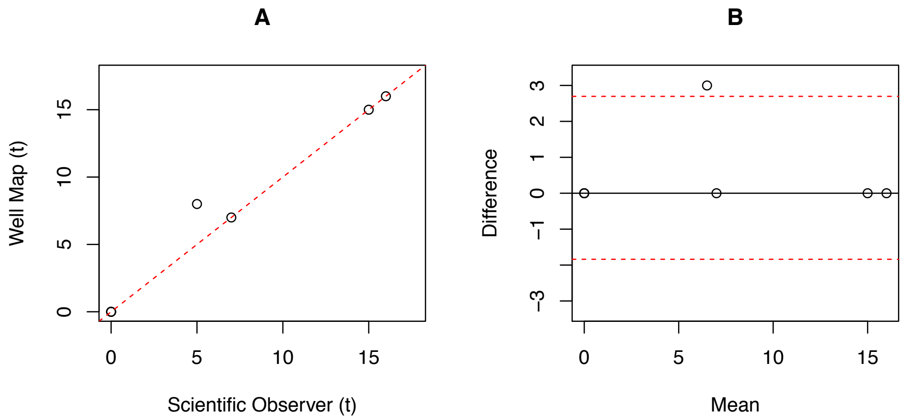


Figure 92: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by fish tank for Well-map and Scientific Observer programme procedures.

Table 113: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by fish tank for Well-map and Scientific Observer programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.985	0.915	0.997
ICC	0.987	0.934	0.998
B&A	0.429	-1.840	2.696

Comparison between SFA EMS and DOS EMS Sampling one

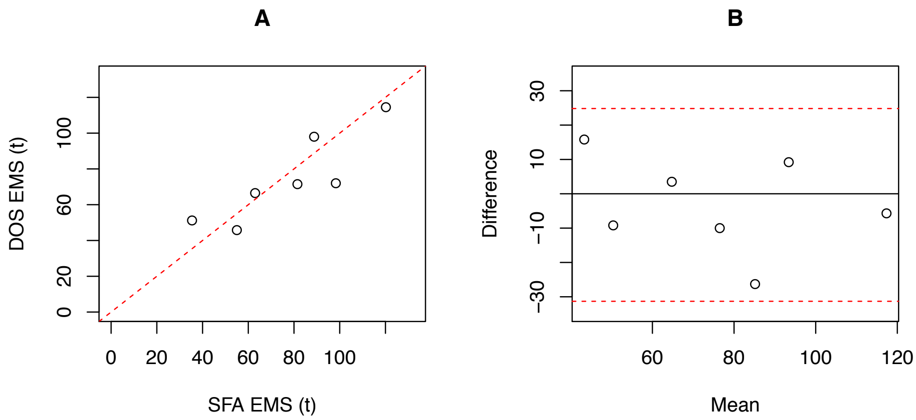


Figure 93: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by fish tank for SFA EMS and DOS EMS S1 procedures.

Table 114: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by fish tank for SFA EMS and DOS EMS S1 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.853	0.410	0.970
ICC	0.872	0.483	0.976
B&A	-3.243	-31.311	24.825

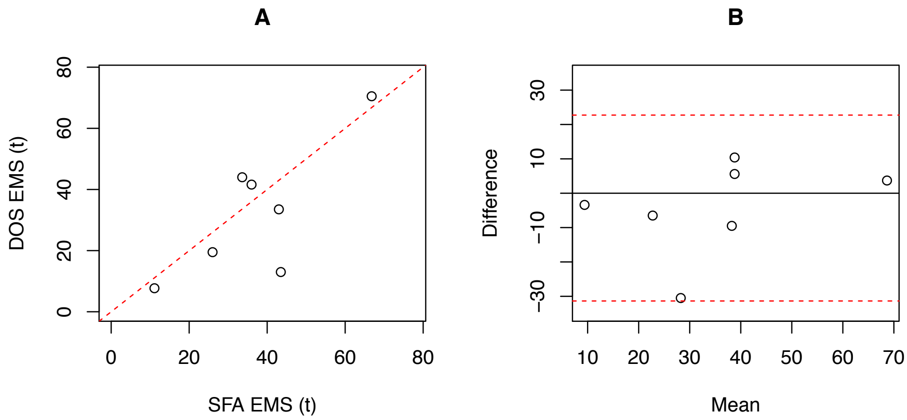


Figure 94: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by fish tank for SFA EMS and DOS EMS S1 procedures.

Table 115: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by fish tank for SFA EMS and DOS EMS S1 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.740	0.145	0.942
ICC	0.770	0.201	0.955
B&A	-4.314	-31.360	22.732

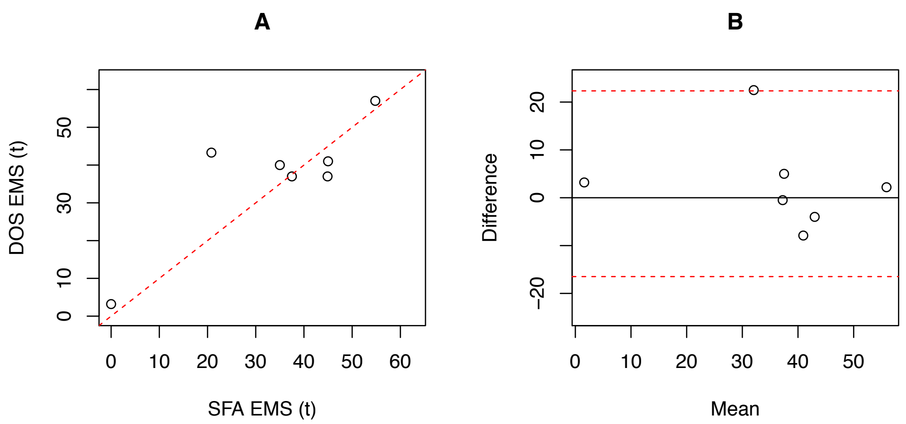


Figure 95: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by fish tank for SFA EMS and DOS EMS S1 procedures.

Table 116: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by fish tank for SFA EMS and DOS EMS S1 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.830	0.330	0.966
ICC	0.852	0.418	0.972
B&A	2.929	-16.479	22.336

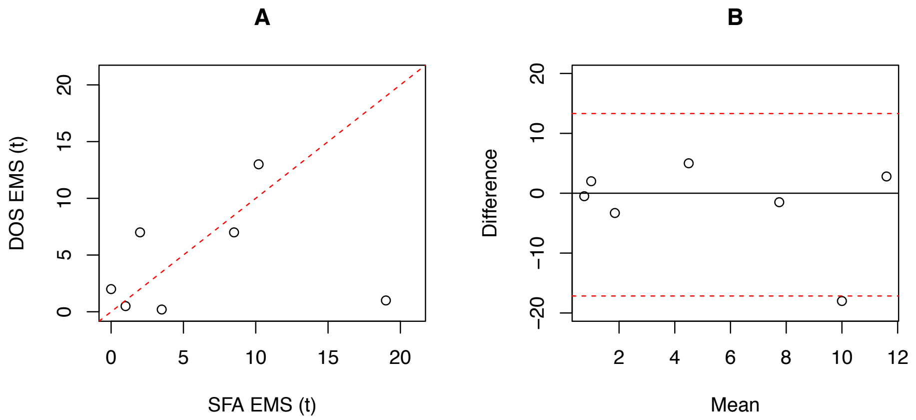


Figure 96: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by fish tank for SFA EMS and DOS EMS S1 procedures.

Table 117: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by fish tank for SFA EMS and DOS EMS S1 procedures. programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.148	-0.557	0.729
ICC	0.197	-0.549	0.789
B&A	-1.929	-17.164	13.307

Comparison between SFA EMS and DOS EMS Sampling two

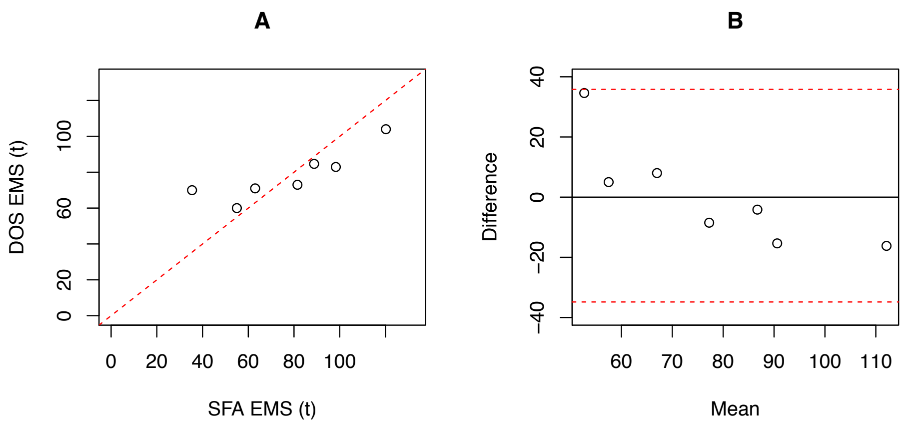


Figure 97: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by fish tank for SFA EMS and DOS EMS S2 procedures.

Table 118: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by fish tank for SFA EMS and DOS EMS S2 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.693	0.358	0.870
ICC	0.731	0.113	0.947
B&A	0.484	-34.846	35.815

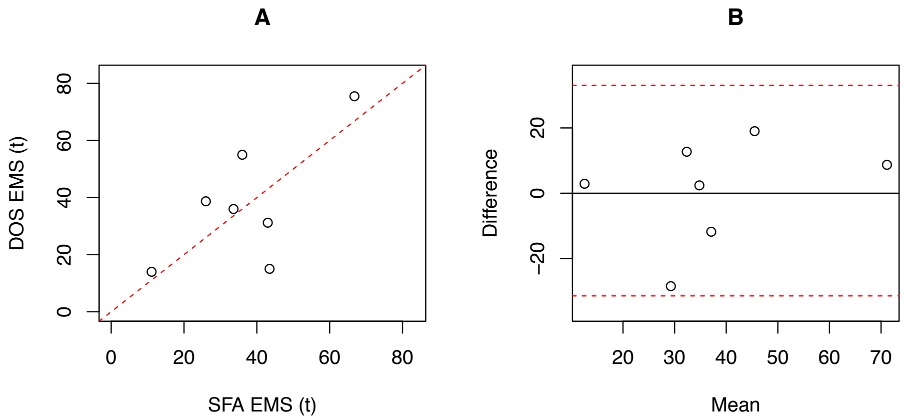


Figure 98: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by fish tank for SFA EMS and DOS EMS S2 procedures.

Table 119: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by fish tank for SFA EMS and DOS EMS S2 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.662	-0.035	0.926
ICC	0.703	0.057	0.941
B&A	0.777	-31.442	32.997

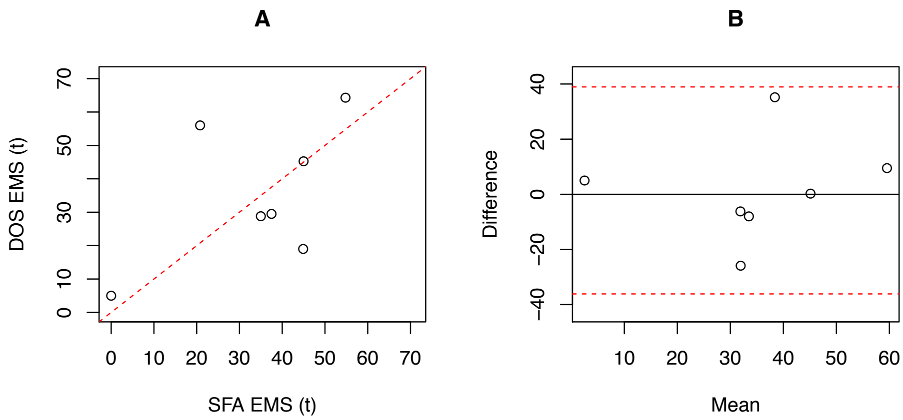


Figure 99: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by fish tank for SFA EMS and DOS EMS S2 procedures.

Table 120: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by fish tank for SFA EMS and DOS EMS S2 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.543	-0.249	0.900
ICC	0.595	-0.131	0.915
B&A	1.407	-36.132	38.946

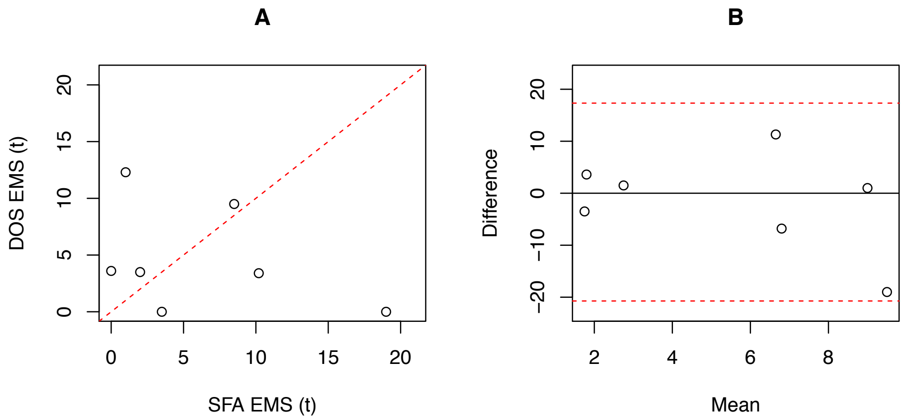


Figure 100: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by fish tank for SFA EMS and DOS EMS S2 procedures.

Table 121: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by fish tank for SFA EMS and DOS EMS S2 procedures. programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	-0.326	-0.808	0.417
ICC	-0.289	-0.806	0.517
B&A	-1.7	-20.729	17.329

Comparison between SFA EMS and Scientific Observer Programme

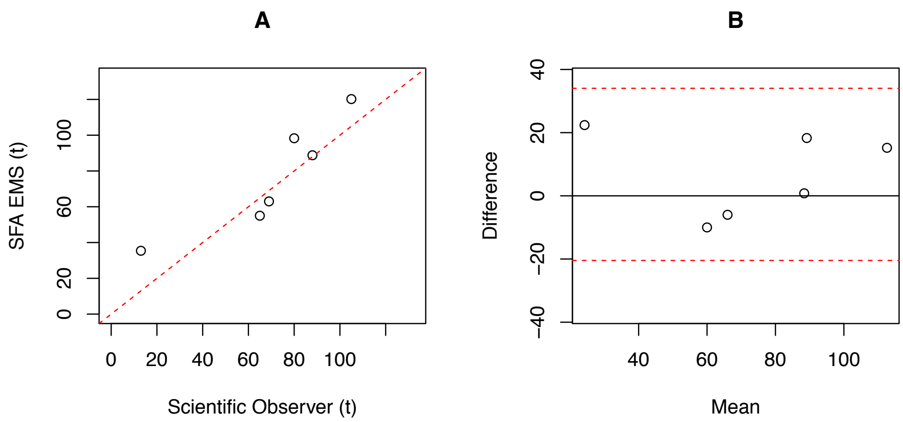


Figure 101: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by fish tank for SFA EMS and Scientific Observer programme procedures.

Table 122: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by fish tank for SFA EMS and Scientific Observer programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.880	0.404	0.981
ICC	0.898	0.513	0.985
B&A	6.783	-20.467	34.034

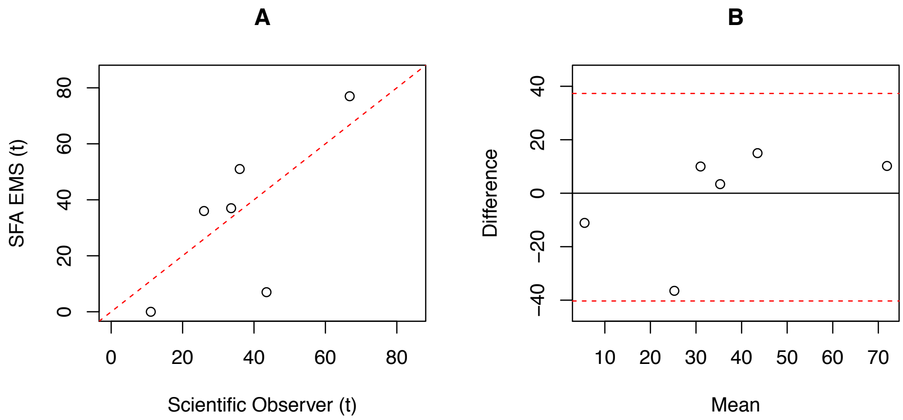


Figure 102: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by fish tank for SFA EMS and Scientific Observer programme procedures.

Table 123: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by fish tank for SFA EMS and Scientific Observer programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.672	-0.010	0.927
ICC	0.718	0.010	0.954
B&A	-1.5	-40.308	37.308

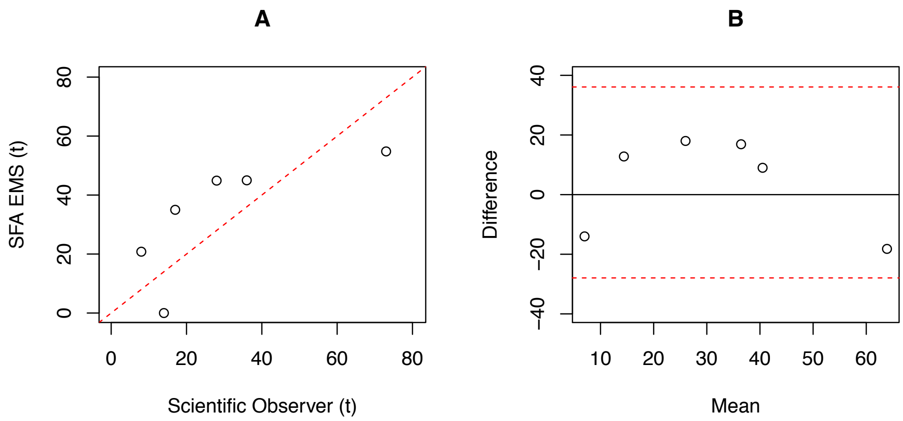


Figure 103: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by fish tank for SFA EMS and Scientific Observer programme procedures.

Table 124: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by fish tank for SFA EMS and Scientific Observer programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.718	-0.032	0.951
ICC	0.757	0.093	0.961
B&A	4.083	-27.937	36.104

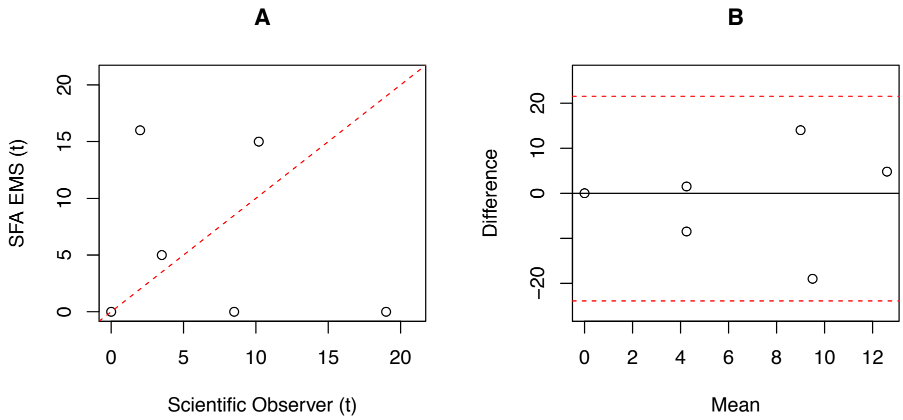


Figure 104: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by fish tank for SFA EMS and Scientific Observer programme procedures.

Table 125: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by fish tank for SFA EMS and Scientific Observer programme procedures. programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	-0.210	-0.826	0.634
ICC	-0.131	-0.773	0.686
B&A	-1.2	-23.931	21.531

Comparison between Scientific Observer Programme and DOS EMS Sampling one

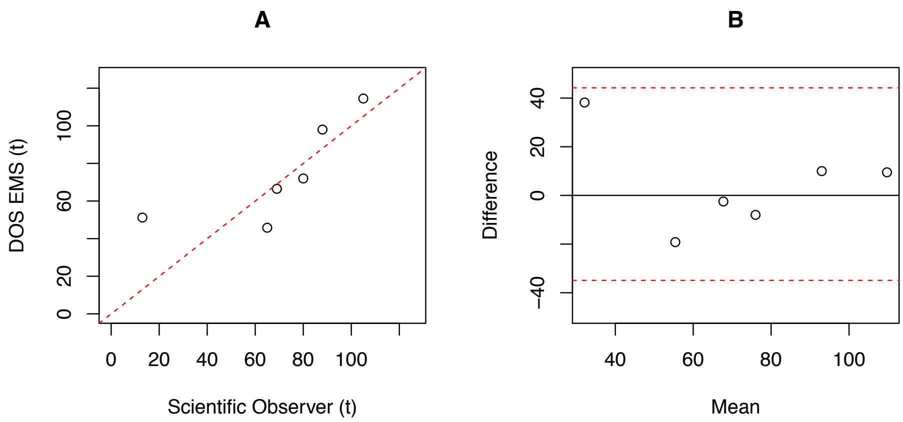


Figure 105: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by fish tank for Scientific Observer programme and DOS EMS S1 procedures.

Table 126: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by fish tank for Scientific Observer programme and DOS EMS S1 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.758	0.053	0.959
ICC	0.793	0.182	0.967
B&A	4.667	-34.908	44.242

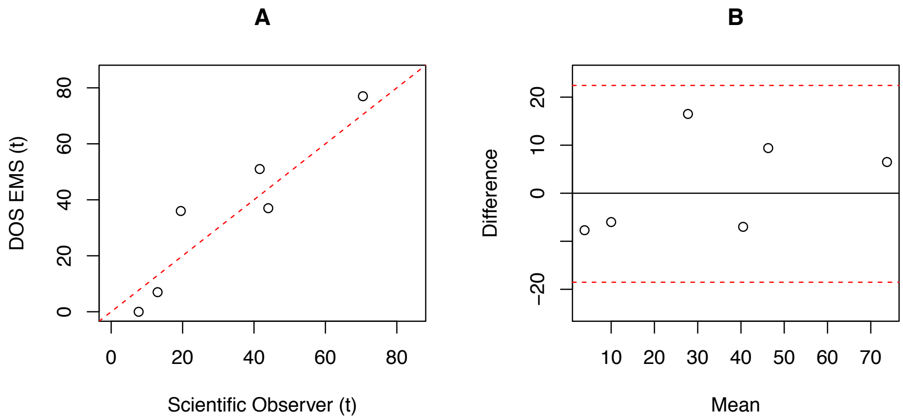


Figure 106: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by fish tank for Scientific Observer programme and DOS EMS S1 procedures.

Table 127: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by fish tank for Scientific Observer programme and DOS EMS S1 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.920	0.617	0.986
ICC	0.933	0.657	0.990
B&A	1.95	-18.531	22.431

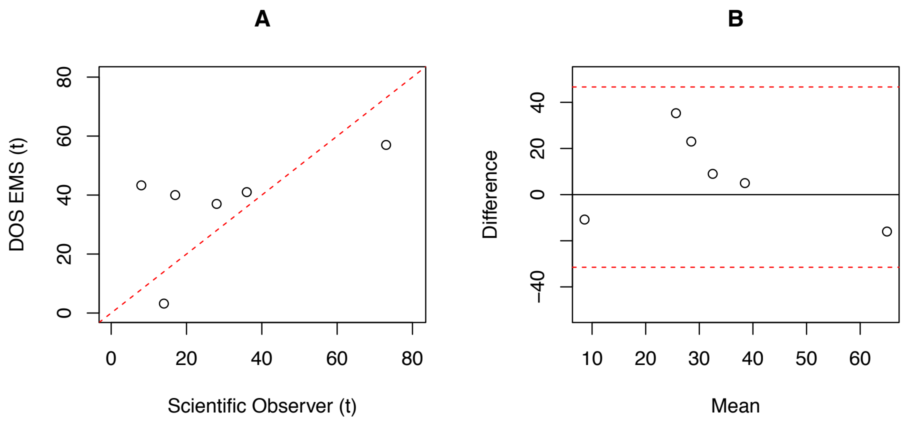


Figure 107: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by fish tank for Scientific Observer programme and DOS EMS S1 procedures.

Table 128: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by fish tank for Scientific Observer programme and DOS EMS S1 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.525	-0.278	0.896
ICC	0.572	-0.240	0.925
B&A	7.583	-31.493	46.660

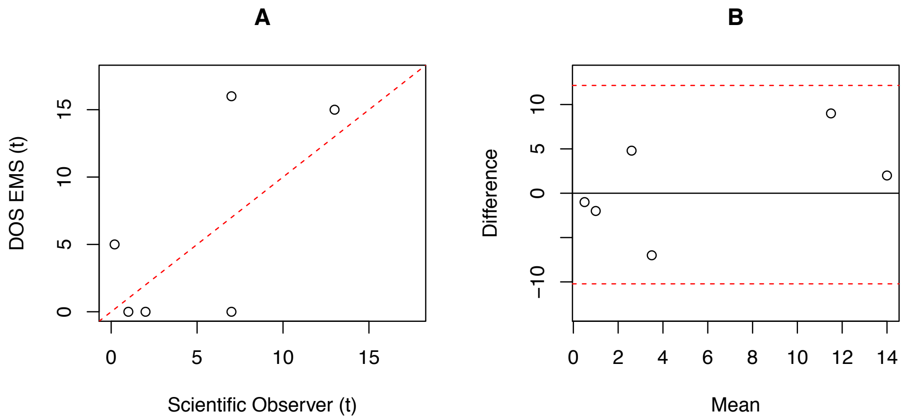


Figure 108: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by fish tank for Scientific Observer programme and DOS EMS S1 procedures.

Table 129: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by fish tank for Scientific Observer programme and DOS EMS S1 procedures. programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.610	-0.116	0.911
ICC	0.662	-0.098	0.943
B&A	0.967	-10.220	12.154

Comparison between Scientific Observer Programme and DOS EMS Sampling two

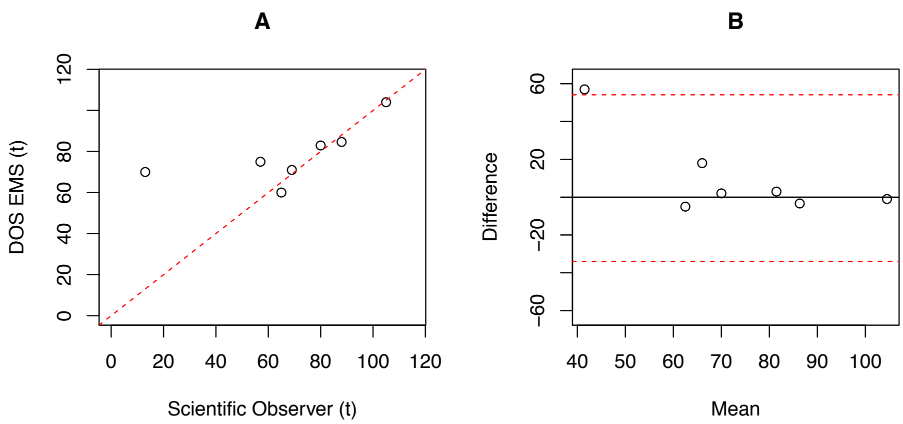


Figure 109: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by fish tank for Scientific Observer programme and DOS EMS S2 procedures.

Table 130: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by fish tank for Scientific Observer programme and DOS EMS S2 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.480	-0.045	0.797
ICC	0.511	-0.247	0.893
B&A	10.084	-33.969	54.137

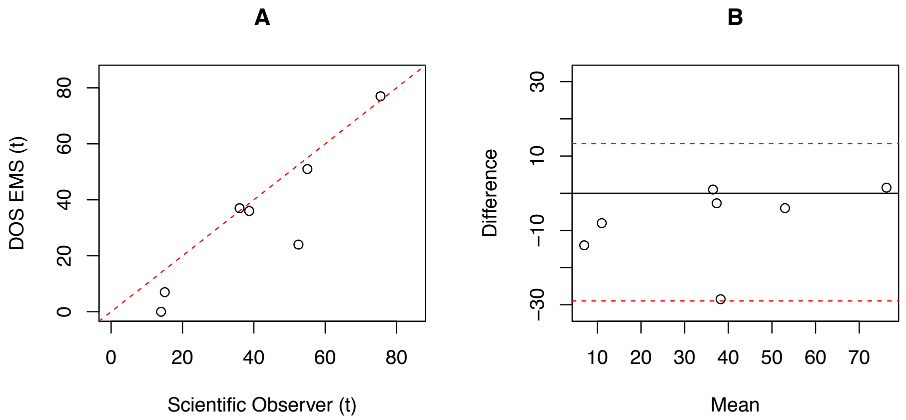


Figure 110: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by fish tank for Scientific Observer programme and DOS EMS S2 procedures.

Table 131: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by fish tank for Scientific Observer programme and DOS EMS S2 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.854	0.463	0.967
ICC	0.869	0.473	0.976
B&A	-7.82	-28.976	13.336

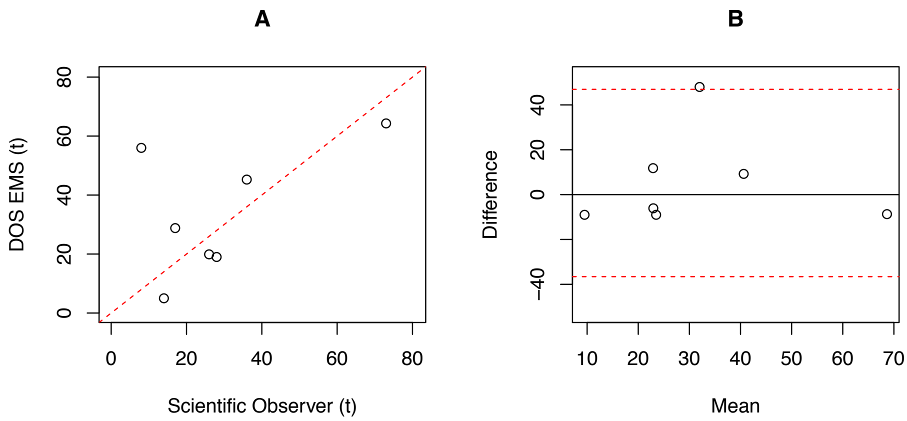


Figure 111: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by fish tank for Scientific Observer programme and DOS EMS S2 procedures.

Table 132: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by fish tank for Scientific Observer programme and DOS EMS S2 procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.518	-0.271	0.891
ICC	0.565	-0.175	0.907
B&A	5.179	-36.582	46.940

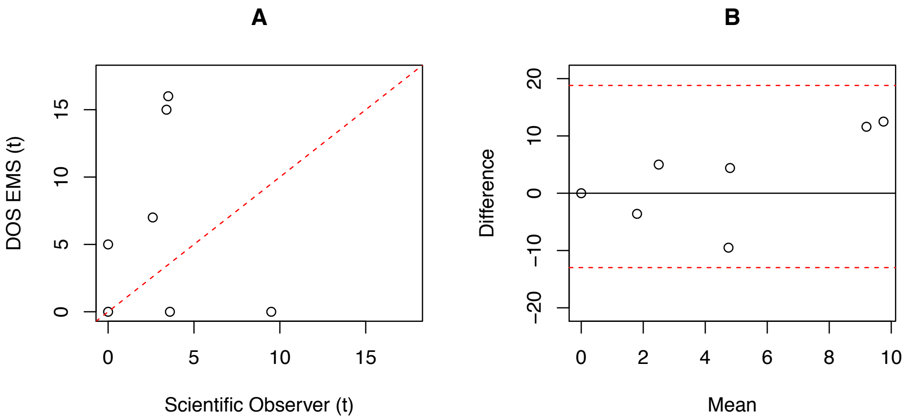


Figure 112: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by fish tank for Scientific Observer programme and DOS EMS S2 procedures.

Table 133: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by fish tank for Scientific Observer programme and DOS EMS S2 procedures. programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	-0.066	-0.560	0.463
ICC	-0.073	-0.711	0.662
B&A	2.914	-12.980	18.808

Comparison between Logbook and Well-map

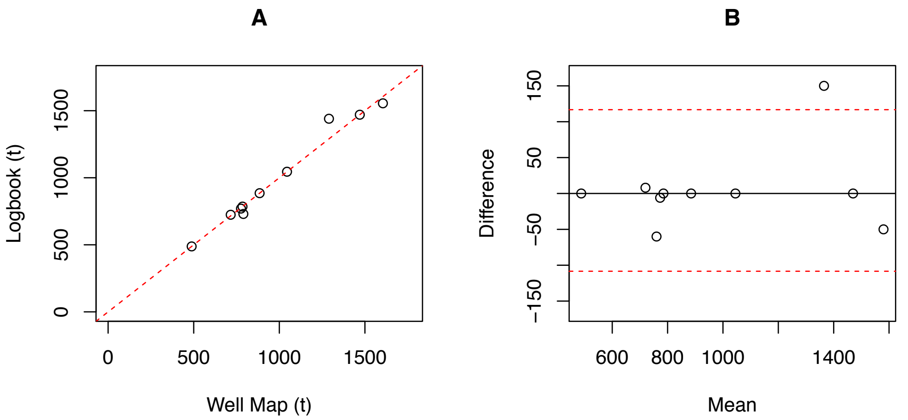


Figure 113: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by trip for Logbook and Well-map procedures.

Table 134: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by trip for Logbook and Well-map procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.988	0.955	0.997
ICC	0.989	0.960	0.997
B&A	4.2	-108.393	116.793

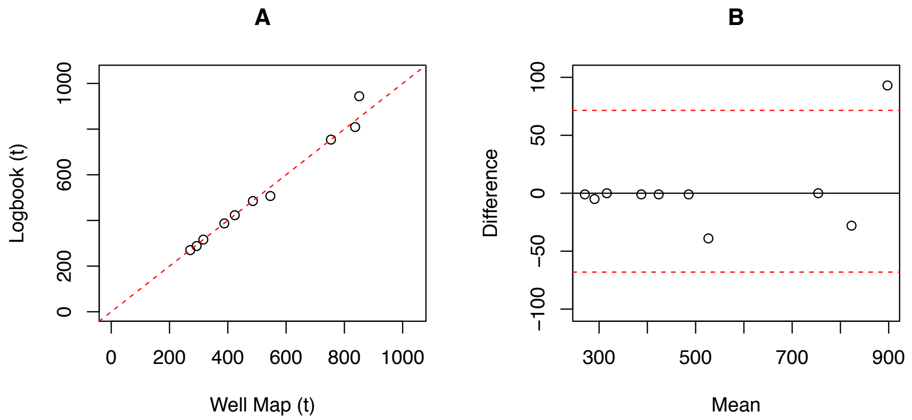


Figure 114: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by trip for Logbook and Well-map procedures.

Table 135: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by trip for Logbook and Well-map procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.988	0.959	0.997
ICC	0.990	0.961	0.997
B&A	1.7	-68.075	71.475

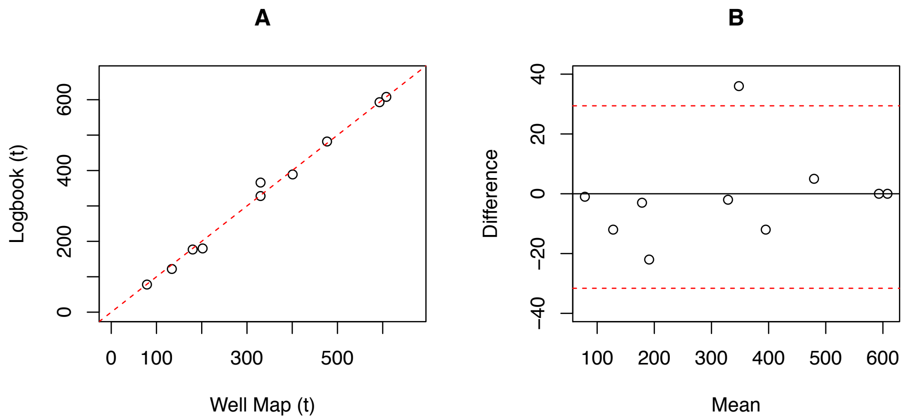


Figure 115: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by trip for Logbook and Well-map procedures.

Table 136: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by trip for Logbook and Well-map procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.997	0.988	0.999
ICC	0.997	0.989	0.999
B&A	-1.1	-31.613	29.413

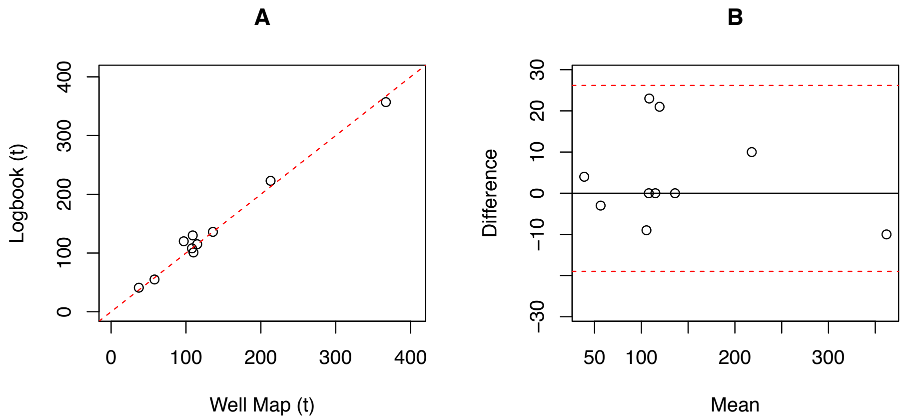


Figure 116: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by trip for Logbook and Well-map procedures.

Table 137: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET)) catch by trip for Logbook and Well-map procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.992	0.969	0.998
ICC	0.993	0.972	0.998
B&A	3.6	-18.972	26.172

Comparison between Logbook and SFA EMS

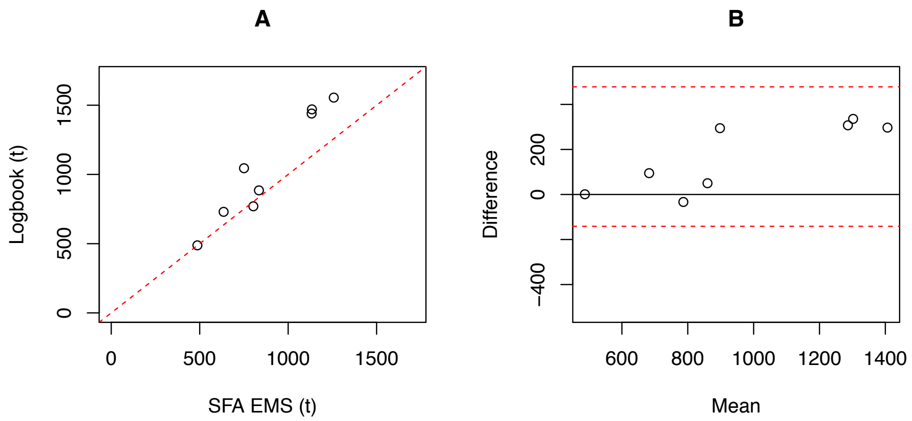


Figure 117: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by trip for Logbook and SFA EMS procedures.

Table 138: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by trip for Logbook and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.786	0.486	0.920
ICC	0.798	0.325	0.955
B&A	168.375	-141.329	478.079

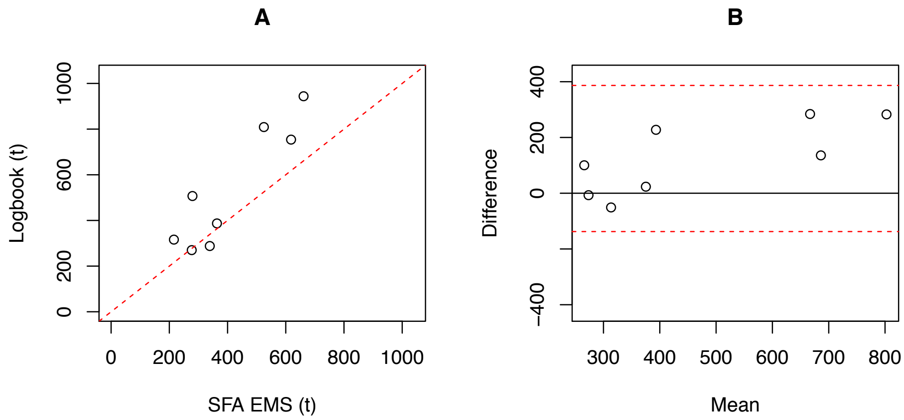


Figure 118: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by trip for Logbook and SFA EMS procedures.

Table 139: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by trip for Logbook and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.701	0.319	0.887
ICC	0.711	0.132	0.933
B&A	124.5	-137.579	386.579

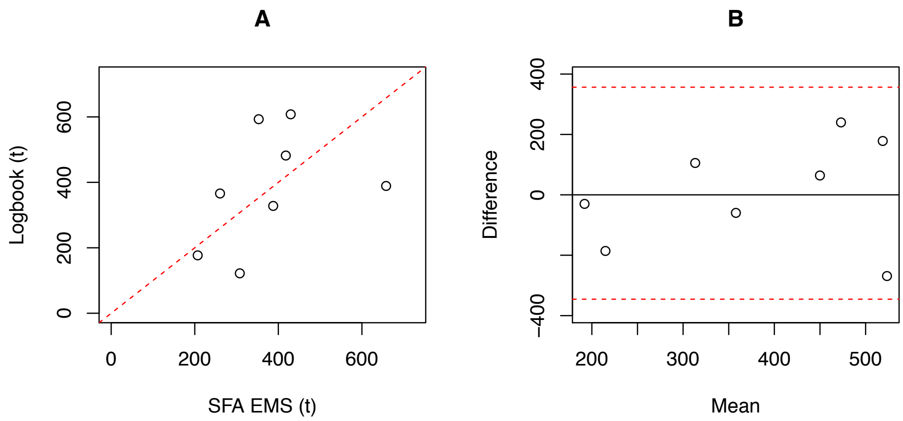


Figure 119: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by trip for Logbook and SFA EMS procedures.

Table 140: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by trip for Logbook and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.383	-0.351	0.825
ICC	0.438	-0.278	0.852
B&A	5.438	-345.621	356.496

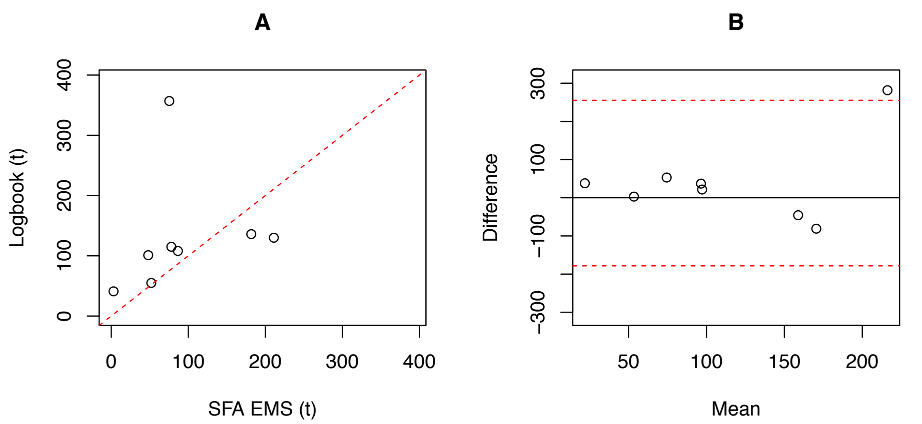


Figure 120: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by trip for Logbook and SFA EMS procedures.

Table 141: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by trip for Logbook and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.165	-0.472	0.688
ICC	0.184	-0.515	0.753
B&A	38.438	-178.394	255.270

Comparison between Logbook and Scientific Observer Programme

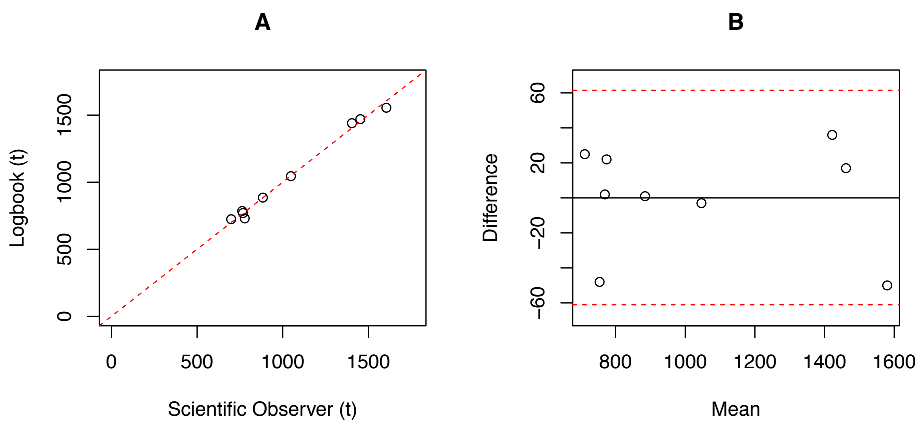


Figure 121: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by trip for Logbook and Scientific Observer Programme procedures.

Table 142: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by trip for Logbook and Scientific Observer Programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.996	0.983	0.999
ICC	0.997	0.986	0.999
B&A	0.222	-61.062	61.507

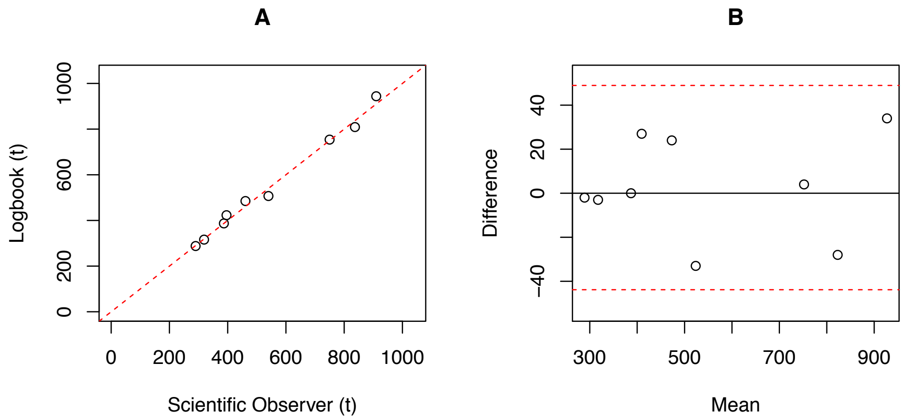


Figure 122: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by trip for Logbook and Scientific Observer Programme procedures.

Table 143: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by trip for Logbook and Scientific Observer Programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.995	0.978	0.999
ICC	0.996	0.982	0.999
B&A	2.556	-43.835	48.946

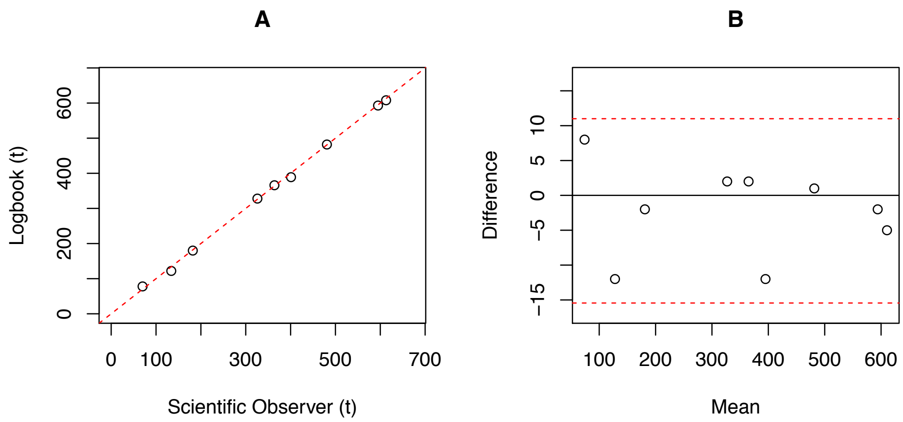


Figure 123: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by trip for Logbook and Scientific Observer Programme procedures.

Table 144: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by trip for Logbook and Scientific Observer Programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.999	0.997	1
ICC	0.999	0.998	1
B&A	-2.222	-15.443	10.998

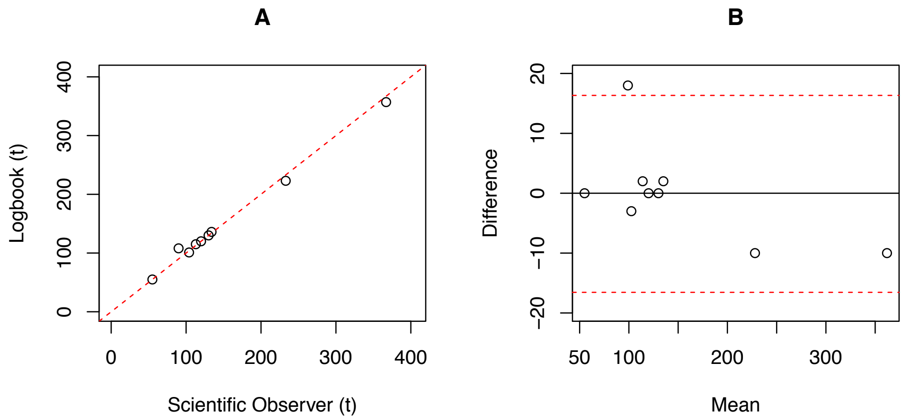


Figure 124: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by trip for Logbook and Scientific Observer Programme procedures.

Table 145: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by trip for Logbook and Scientific Observer Programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.996	0.987	0.999
ICC	0.996	0.986	0.999
B&A	-0.111	-16.556	16.334

Comparison between Well-map and SFA EMS

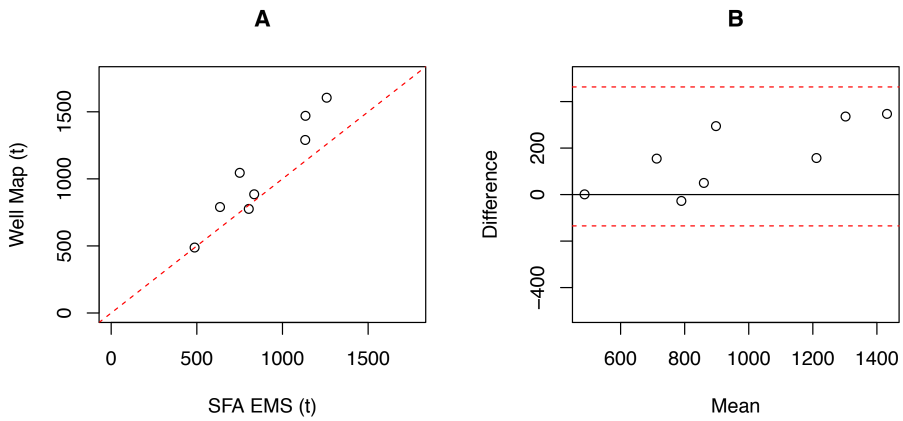


Figure 125: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by trip for Well-map and SFA EMS procedures.

Table 146: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by trip for Well-map and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	Lower 95% CI	Upper 95% CI
CCC	0.788	0.470	0.925
ICC	0.799	0.329	0.956
B&A	164.125	-134.701	462.951

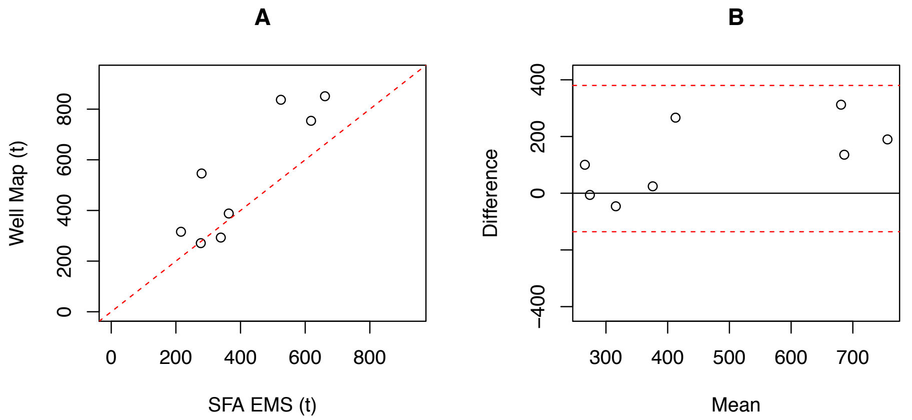


Figure 126: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by trip for Well-map and SFA EMS procedures.

Table 147: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by trip for Well-map and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.688	0.265	0.889
ICC	0.697	0.106	0.930
B&A	122.125	-135.832	380.082

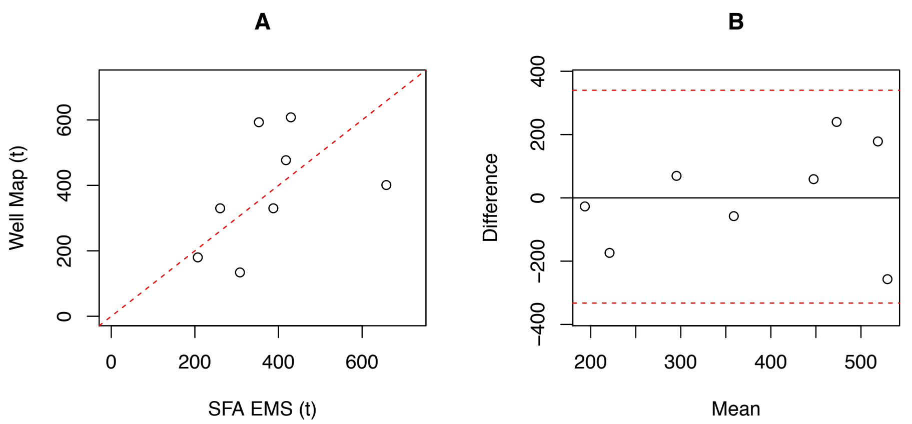


Figure 127: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by trip for Well-map and SFA EMS procedures.

Table 148: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by trip for Well-map and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.425	-0.308	0.841
ICC	0.478	-0.231	0.865
B&A	3.938	-332.294	340.169

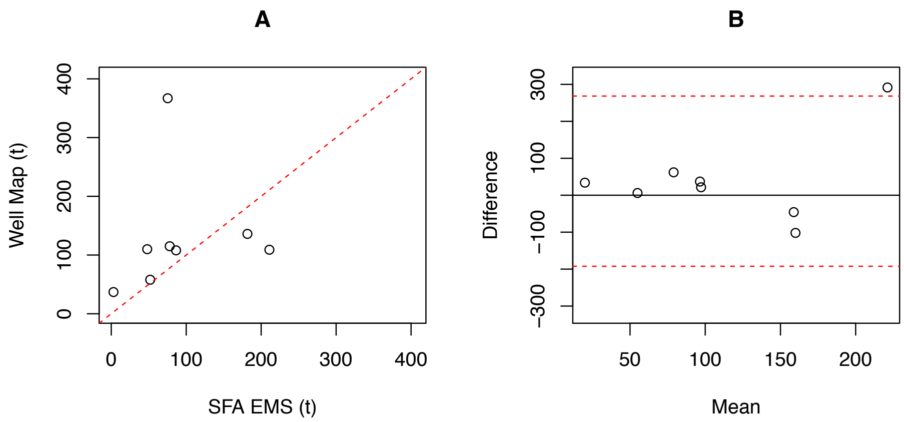


Figure 128: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by trip for Well-map and SFA EMS procedures.

Table 149: Summary statistic of the concordance analysis; and their 95% confidence interval, of total retained bigeye tuna (BET) catch by trip for Well-map and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.110	-0.511	0.656
ICC	0.130	-0.554	0.728
B&A	38.063	-192.290	268.415

Comparison between Well-map and Scientific Observer Programme

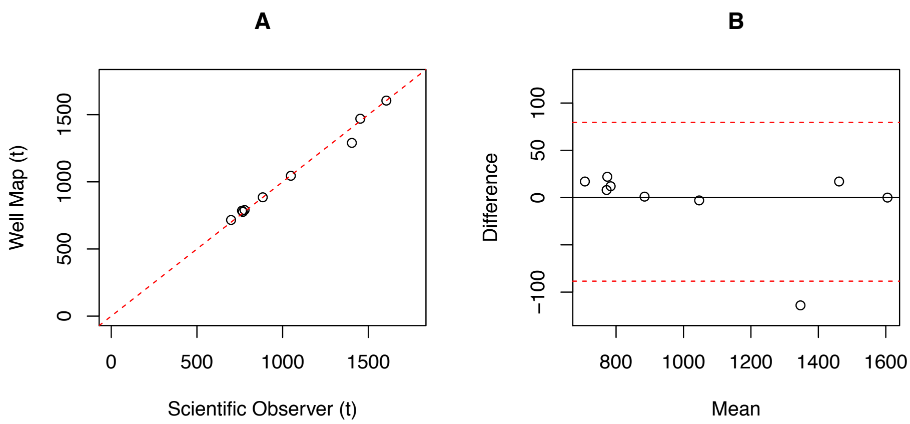


Figure 129: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by trip for Well-map and Scientific Observer Programme procedures.

Table 150*:* Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by trip for Well-map and Scientific Observer Programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.992	0.970	0.998
ICC	0.993	0.973	0.998
B&A	-4.444	-88.403	79.515

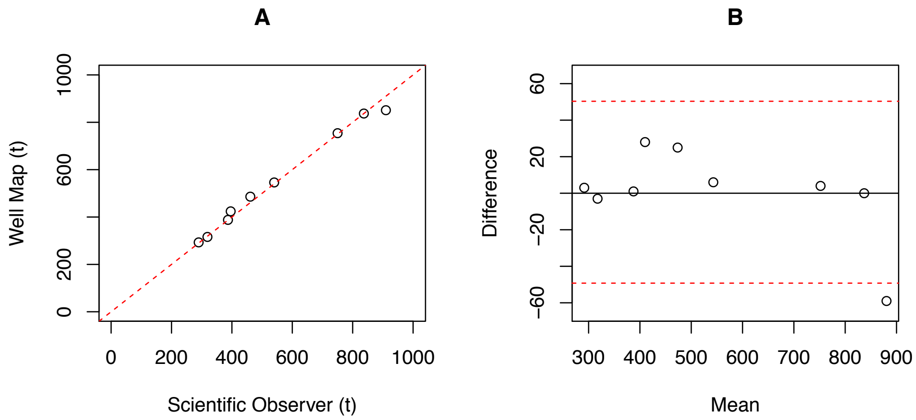


Figure 130: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by trip for Well-map and Scientific Observer Programme procedures.

Table 151: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by trip for Well-map and Scientific Observer Programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.994	0.979	0.998
ICC	0.995	0.978	0.999
B&A	0.556	-49.235	50.346

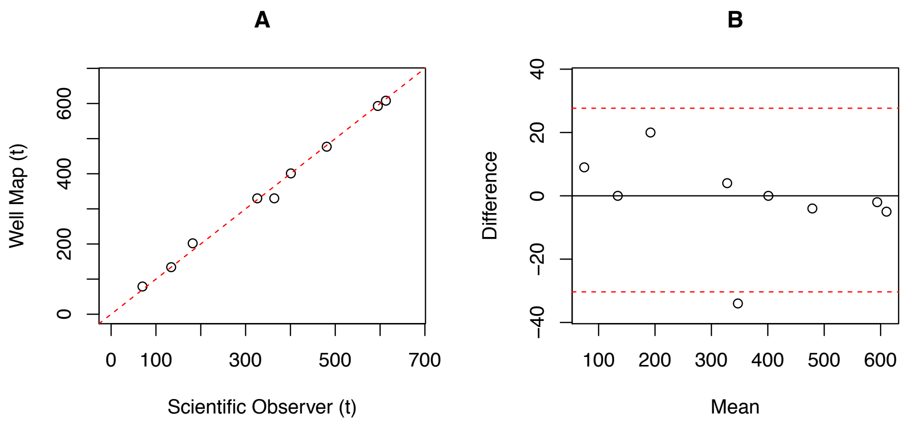


Figure 131: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by trip for Well-map and Scientific Observer Programme procedures.

Table 152: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by trip for Well-map and Scientific Observer Programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.997	0.989	0.999
ICC	0.997	0.990	0.999
B&A	-1.333	-30.333	27.667

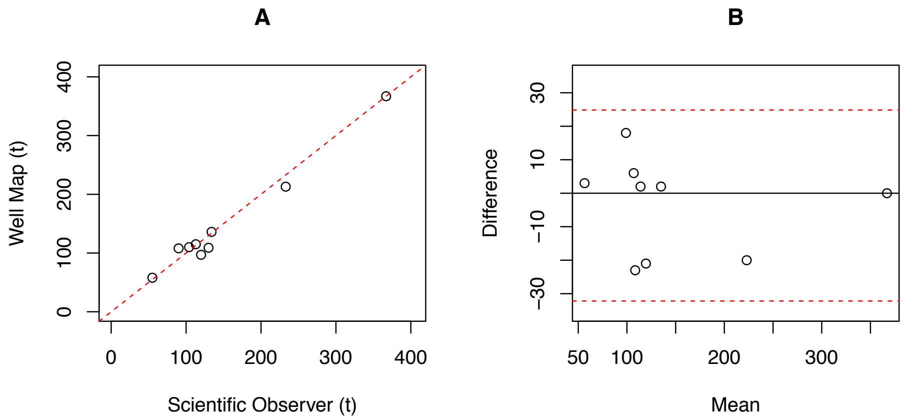


Figure 132: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by trip for Well-map and Scientific Observer Programme procedures.

Table 153: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained bigeye tuna (BET) catch by trip for Well-map and Scientific Observer Programme procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.988	0.947	0.997
ICC	0.989	0.955	0.997
B&A	-3.667	-32.180	24.846

Comparison between Scientific Observer Programme and SFA EMS

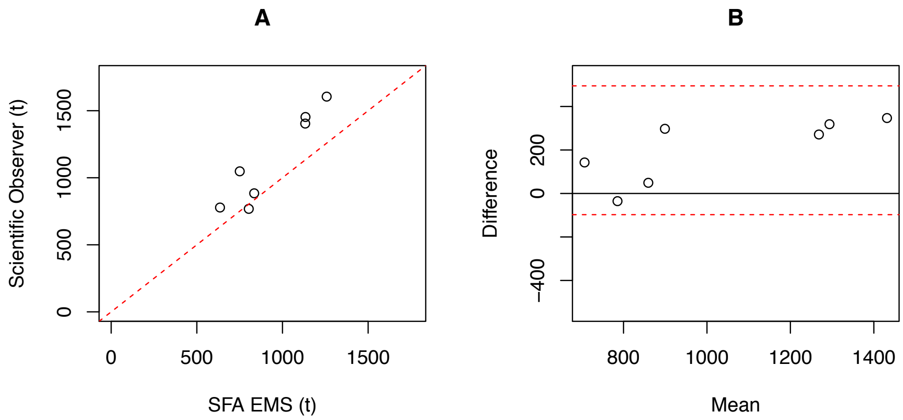


Figure 133: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by trip for Scientific Observer Programme and SFA EMS procedures.

Table 154: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by trip for Scientific Observer Programme and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.695	0.283	0.890
ICC	0.701	0.053	0.940
B&A	198.714	-97.593	495.022

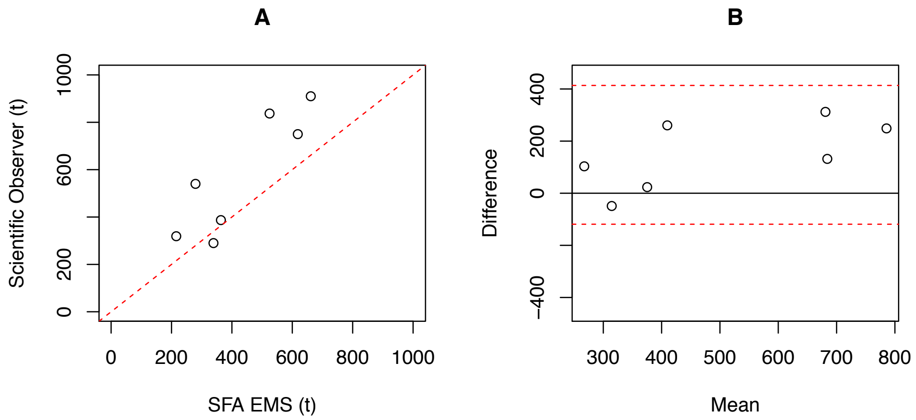


Figure 134: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by trip for Scientific Observer Programme and SFA EMS procedures.

Table 155: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by trip for Scientific Observer Programme and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.644	0.167	0.877
ICC	0.649	-0.042	0.928
B&A	147.286	-119.009	413.581

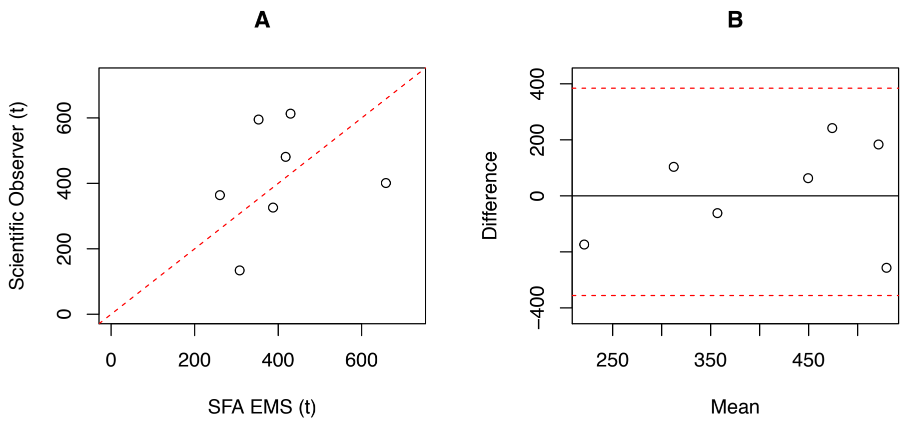


Figure 135: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by trip for Scientific Observer Programme and SFA EMS procedures.

Table 156: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by trip for Scientific Observer Programme and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.220	-0.550	0.787
ICC	0.290	-0.476	0.824
B&A	14.214	-355.868	384.297

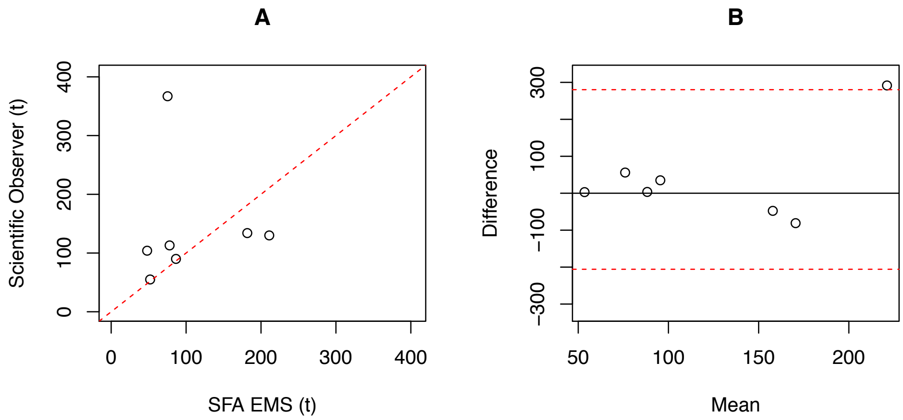


Figure 136: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by trip for Scientific Observer Programme and SFA EMS procedures.

Table 157: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained bigeye tuna (BET) catch by trip for Scientific Observer Programme and SFA EMS procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	-0.001	-0.613	0.612
ICC	0.024	-0.660	0.713
B&A	37.214	-205.84	280.269

Comparison between Scientific Observer Programme and Unloading

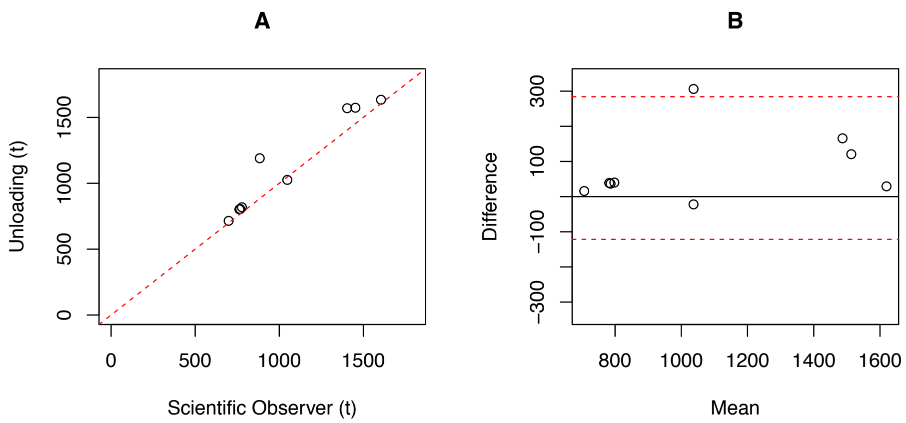


Figure 137: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained tuna catch by trip for Scientific Observer Programme and Unloading procedures.

Table 158: **Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained tuna catch by trip for Scientific Observer Programme and Unloading procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).**

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.935	0.769	0.983
ICC	0.941	0.779	0.986
B&A	81.333	-121.638	284.305

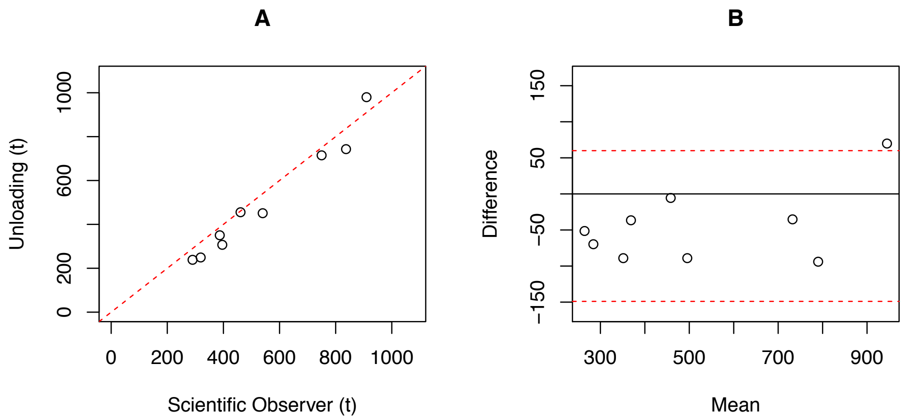


Figure 138: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained skipjack tuna (SKJ) catch by trip for Scientific Observer Programme and Unloading procedures.

Table 159: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained skipjack tuna (SKJ) catch by trip for Scientific Observer Programme and Unloading procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.959	0.861	0.989
ICC	0.964	0.859	0.992
B&A	-44.527	-149.013	59.958

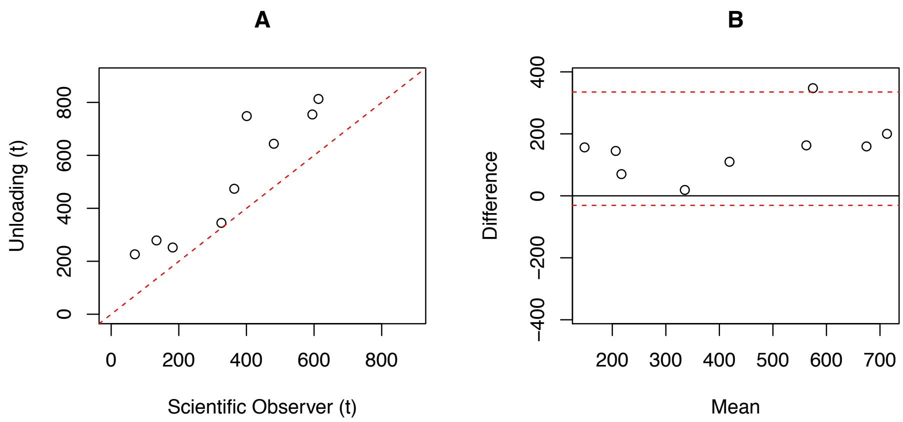


Figure 139: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained yellowfin tuna (YFT) catch by trip for Scientific Observer Programme and Unloading procedures.

Table 160: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained yellowfin tuna (YFT) catch by trip for Scientific Observer Programme and Unloading procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.715	0.362	0.889
ICC	0.711	0.181	0.925
B&A	152.217	-30.721	335.155

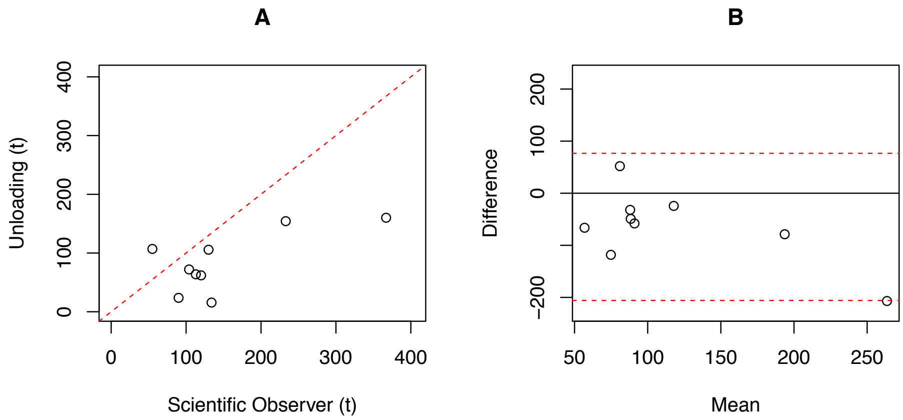
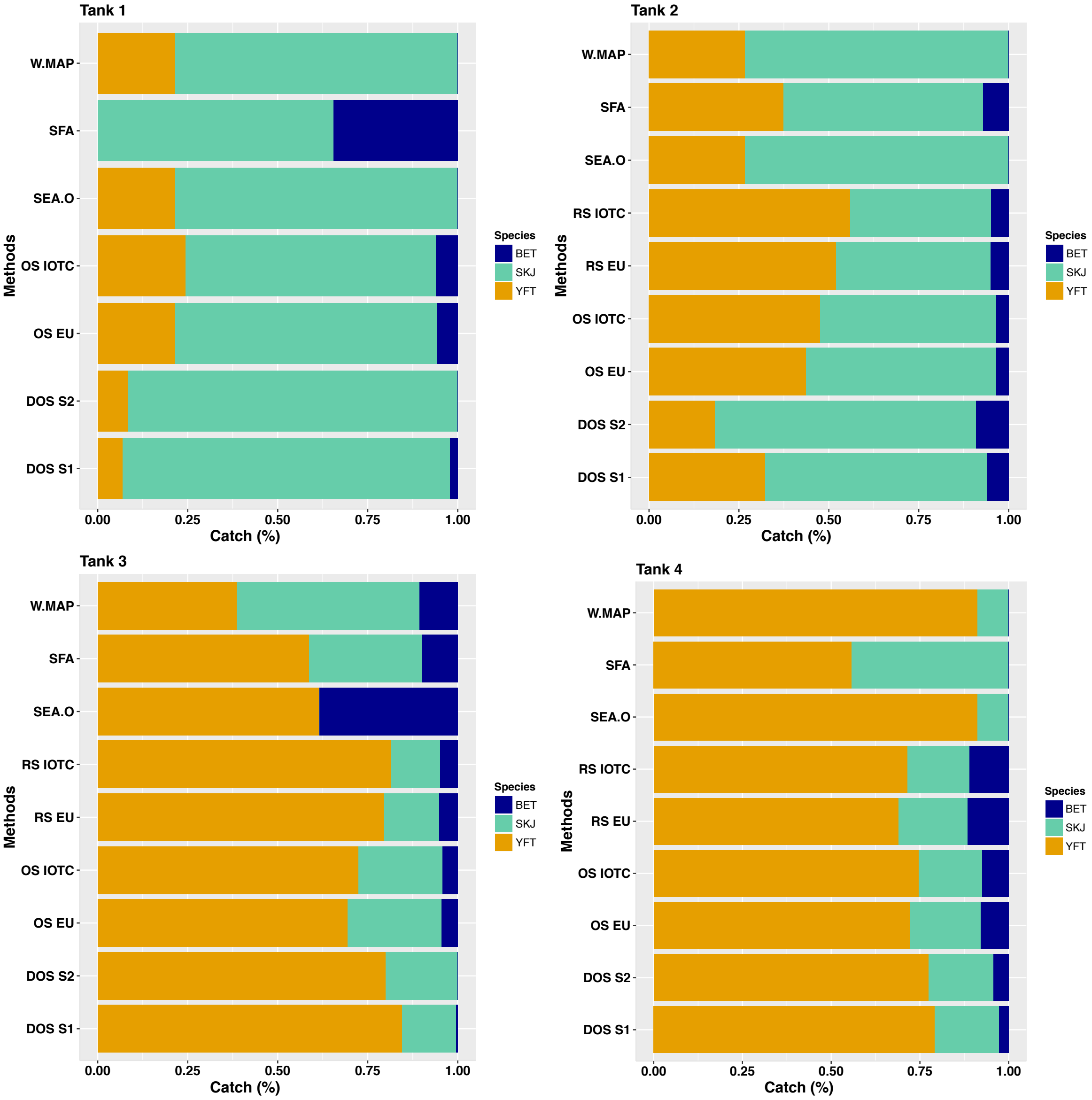


Figure 140: Scatter plot (A) and Bland and Altman plot with 95% limits of agreement (red dot line) (B) of total retained bigeye tuna (BET) catch by trip for Scientific Observer Programme and Unloading procedures.

Table 161: Summary statistic of the concordance analysis, and their 95% confidence interval, of total retained bigeye tuna (BET) catch by trip for Scientific Observer Programme and Unloading procedures. Concordance Correlation Coefficient (CCC), Intraclass Correlation Coefficient (ICC) and Bland and Altman method (B&A).

	Coefficient estimate	**Lower 95% CI**	**Upper 95% CI**
CCC	0.405	-0.009	0.701
ICC	0.357	-0.320	0.804
B&A	-64.631	-205.866	76.603

7.4 Comparison of Species and Size Composition for Retained Tina



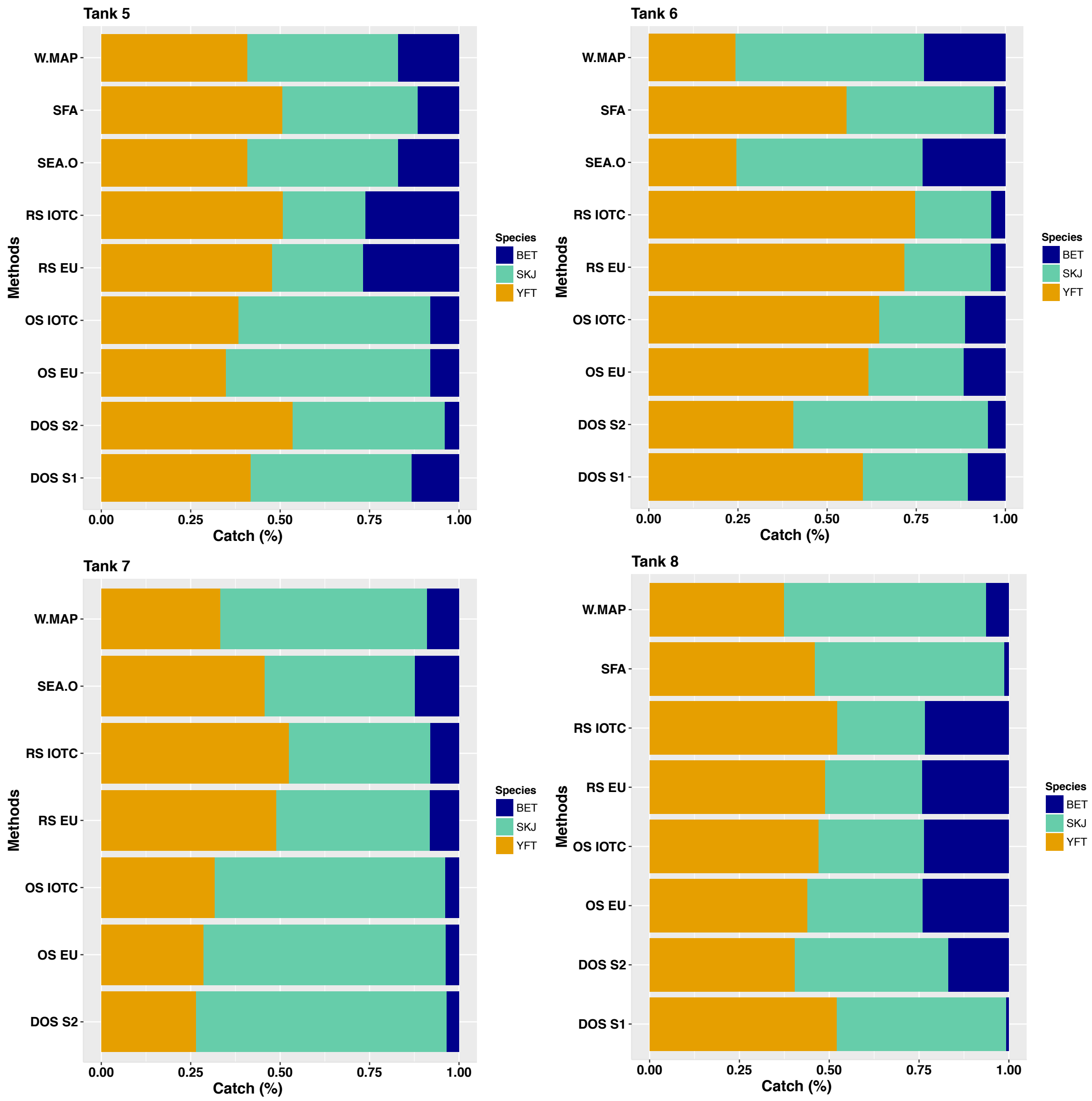


Figure 141: Proportion of tuna by species in the catch estimated by each method (DOS EMS S1 (DOS S1), DOS EMS S2 (DOS S2), Oversampling EU (OS EU), Oversampling IOTC (OS IOTC), Regular sampling EU (RS EU), Regular sampling IOTC (RS IOTC), Scientific Observer Programme (Sea. O), SFA EMS (SFA) and Well-map (W.MAP)) for each sampled fish tank (1 to 8).

Table 162: Results of chi-square test for proportion of tuna by species in the catch estimated by each method (DOS EMS S1 (DOS S1), DOS EMS S2 (DOS S2), Oversampling EU (OS EU), Oversampling IOTC (OS IOTC), Regular sampling EU (RS EU), Regular sampling IOTC (RS IOTC), Scientific Observer Programme (Sea. O), SFA EMS (SFA) and Well-map (W.MAP)) for each sampled fish tank (1 to 8). Levels of significance were *p < 0.05, **p < 0.01 and ***p < 0.001). Yellow boxes indicate no data available for analysis.

Tank 1	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	SFA	W.MAP
DOS S1									
DOS S2	1.373								
OS EU	5.973*	8.921**							
OS IOTC	7.411*	10.642**							
RS EU									
RS IOTC									
SEA.O	5.576*	4.221*	3.953	4.416					
SFA	19.124***	27.802***	28.119***	27.692***			34.996***		
W.MAP	5.576*	4.221*	3.953	4.416			0	34.996***	

Tank 2	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	SFA	W.MAP
DOS S1									
DOS S2	5.845*								
OS EU	3.532	17.344***							
OS IOTC	5.578	21.062***							
RS EU	8.471*	25.241***	2.120						
RS IOTC	11.624**	29.775***		3.219					
SEA.O	8.137*	11.234**	11.623**	14.856***	21.498***	25.353***			
SFA	0.869	9.967**	2.120	3.219	4.715	7.183*	12.171**		
W.MAP	8.137*	11.234**	11.623**	14.856***	21.498***	25.353***	0	12.171**	

Tank 3	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	SFA	W.MAP
DOS S1									
DOS S2	0.755								
OS EU	4.377	4.215							
OS IOTC	3.203	3.373							
RS EU	2.225	4.02	1.734						
RS IOTC	2.09	4.278		2.420					
SEA.O	21.196***	30.008***	16.417***	16.216***	13.303**	13.301**			
SFA	8.869**	9.650**	1.734	2.420	4.777	5.917*	8.5093*		
W.MAP	26.802***	27.514***	13.775***	16.29***	23.273***	25.463***	13.759***	4.182	

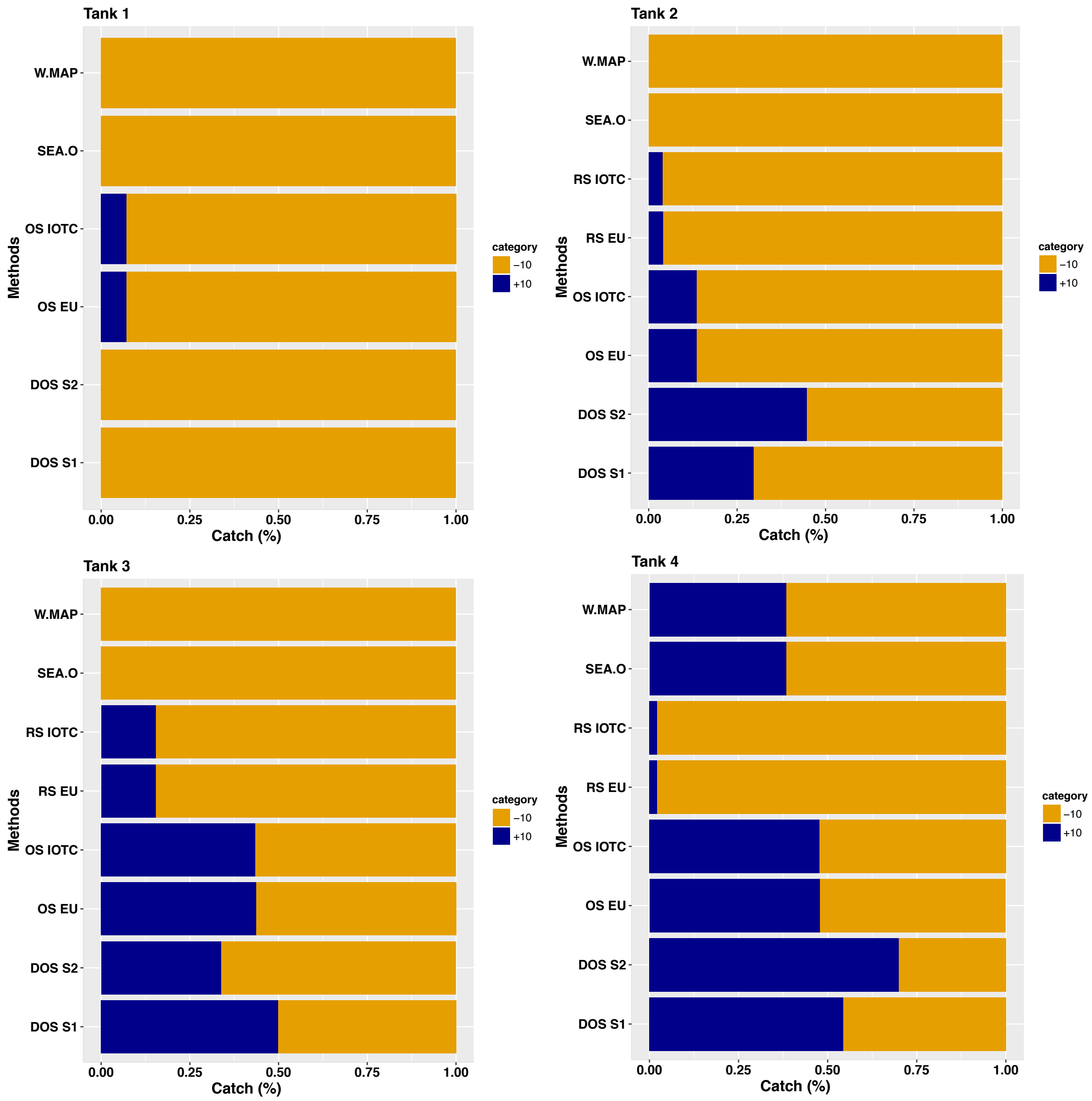
Tank 4	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	SFA	W.MAP
DOS S1									
DOS S2	0.274								
OS EU	2.073	1.030							
OS IOTC	1.650	0.701							
RS EU	3.896	2.538	16.998***						
RS IOTC	3.387	2.098		18.558***					
SEA.O	5.363*	7.033*	11.438***	9.589**	13.661***	11.958***			
SFA	14.799***	17.014***	16.998***	18.558***	17.481***	18.272***	27.383***		
W.MAP	5.363*	7.033*	11.438***	9.589**	13.661***	11.958***	0	27.383***	

Tank 5	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	SFA	W.MAP
DOS S1									
DOS S2	5.684								
OS EU	3.253	6.529*							
OS IOTC	1.932	4.286							
RS EU	10.277**	18.905***	23.354***						
RS IOTC	11.594**	19.219***		20.622***					
SEA.O	0.536	8.318*	5.478	3.959	6.407*	7.781*			
SFA	1.468	3.386	6.784*	4.291	8.048*	8.457*	2.074		
W.MAP	0.536	8.318*	5.478	3.959	6.407*	7.781*	0	2.074	

Tank 6	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	SFA	W.MAP
DOS S1									
DOS S2	9.187**								
OS EU	0.151	12.79**							
OS IOTC	0.522	14.929***							
RS EU	2.842	13.682***	3.179						
RS IOTC	3.680	16.05***		2.944					
SEA.O	17.668***	11.124**	20.787***	23.741***	30.994***	33.576***			
SFA	3.948	3.038	5.778	6.777*	4.210	5.667*	18.498***		
W.MAP	18.145***	11.085**	21.379***	24.385***	31.578***	34.208***	0.007	18.724***	

Tank 7	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	SFA	W.MAP
DOS S1									
DOS S2									
OS EU		0.090							
OS IOTC		0.493							
RS EU		11.648**	0.006**						
RS IOTC		14.126***		0.006**					
SEA.O		11.199**	9.4602**	7.1926*	0.65307	0.95718			
SFA									
W.MAP		3.347	2.519	1.735	4.105	5.934	3.202		

Tank 8	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	SFA	W.MAP
DOS S1									
DOS S2	11.78**								
OS EU	18.67***	2.394							
OS IOTC	19.006***	3.346							
RS EU	19.554***	4.016	0.586						
RS IOTC	19.998***	5.219		0.554					
SEA.O									
SFA	0.630	12.001**	21.415***	22.317***	22.845***	23.645***			
W.MAP	5.234	4.563	12.89**	14.355***	14.806***	16.158***		3.327	


Tank 1
Tank 2
Tank 3
Tank 4
Methods
W.MAP
SEA.O
RS IOTC
RS EU
OS IOTC
OS EU
DOS S2
DOS S1
0.00
0.25
0.50
0.75
1.00
Catch (%)
category
−10
+10

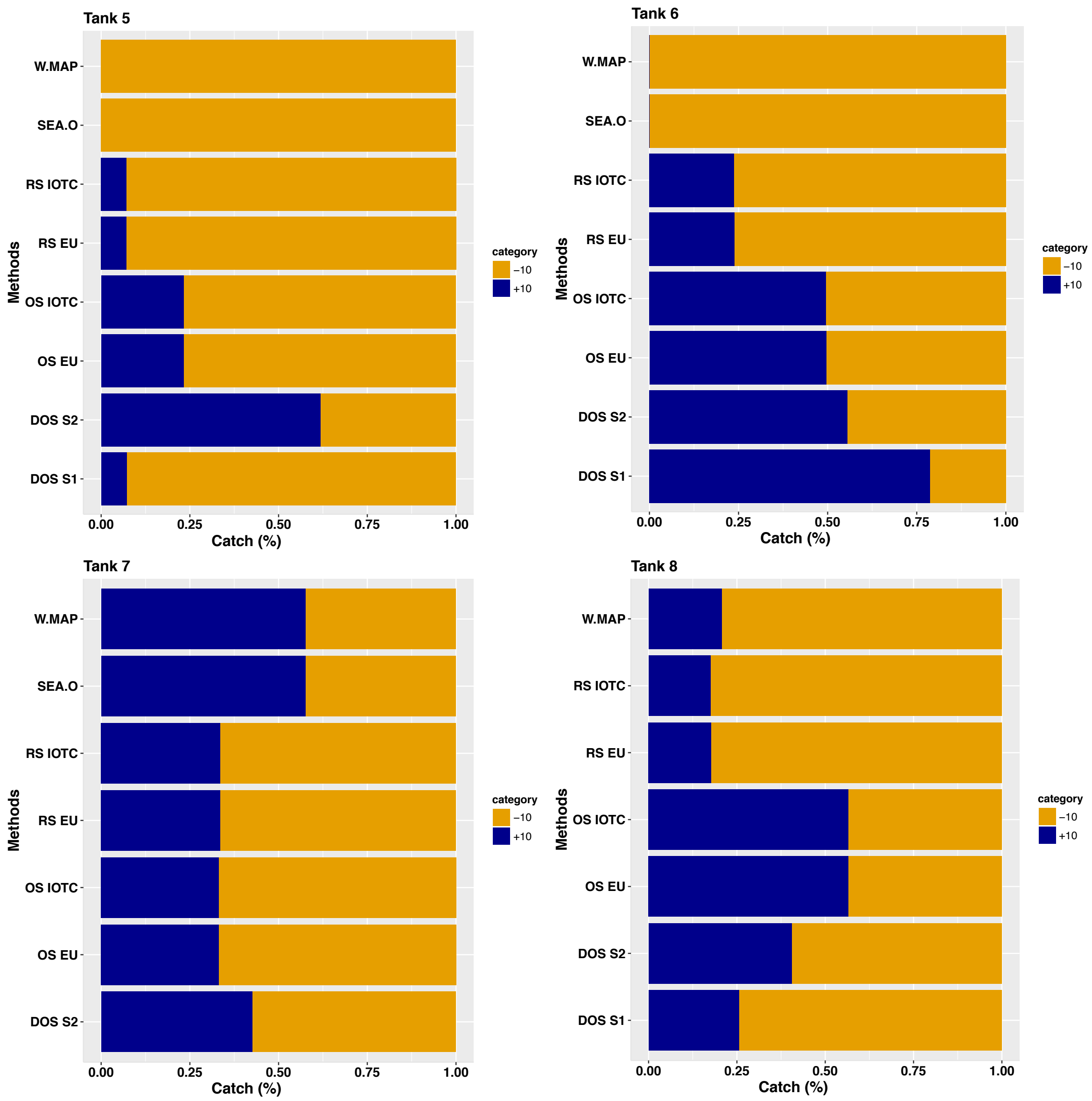


Figure 142: Proportion of yellowfin tuna (YFT) by commercial size category in the catch estimated by each method (DOS EMS S1 (DOS S1), DOS EMS S2 (DOS S2), Oversampling EU (OS EU), Oversampling IOTC (OS IOTC), Regular sampling EU (RS EU), Regular sampling IOTC (RS IOTC), Scientific Observer Programme (Sea. O), SFA EMS (SFA) and Well-map (W.MAP)) for each sampled fish tank (1 to 8).

Table 163: Results of chi-square test for proportion of yellowfin tuna (YFT) by commercial size category in the catch estimated by each method (DOS EMS S1 (DOS S1), DOS EMS S2 (DOS S2), Oversampling EU (OS EU), Oversampling IOTC (OS IOTC), Regular sampling EU (RS EU), Regular sampling IOTC (RS IOTC), Scientific Observer Programme (Sea. O) and Well-map (W.MAP)) for each sampled fish tank (1 to 8). Levels of significance were *p < 0.05, **p < 0.01 and ***p < 0.001). Yellow boxes indicate no data available for analysis. Grey boxes indicate no analysis performed between two variables.

Tank 1	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	W.MAP
DOS S1								
DOS S2								
OS EU	0.243	0.378						
OS IOTC	0.243	0.378						
RS EU								
RS IOTC								
SEA.O			1.042	1.042				
W.MAP			1.042	1.042				

Tank 2	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	W.MAP
DOS S1								
DOS S2	1.246							
OS EU	3.362	7.678**						
OS IOTC	3.365	7.683**						
RS EU	10.809***	17.363***	2.738					
RS IOTC	11.049***	17.672***		2.882				
SEA.O	10.02**	15.292***	4.191*	4.190*	1.211	1.152		
W.MAP	10.02**	15.292***	4.191*	4.190*	1.211	1.152		

Tank 3	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	W.MAP
DOS S1								
DOS S2	2.572							
OS EU	0.353	1.043						
OS IOTC	0.370	1.010						
RS EU	12.559***	4.687*	9.285**					
RS IOTC	12.559***	4.687*		9.19**				
SEA.O	6.893**	3.860	5.590*	5.557**	1.432	1.432		
W.MAP	20.63***	12.672***	17.425***	17.335***	4.984*	4.984*		

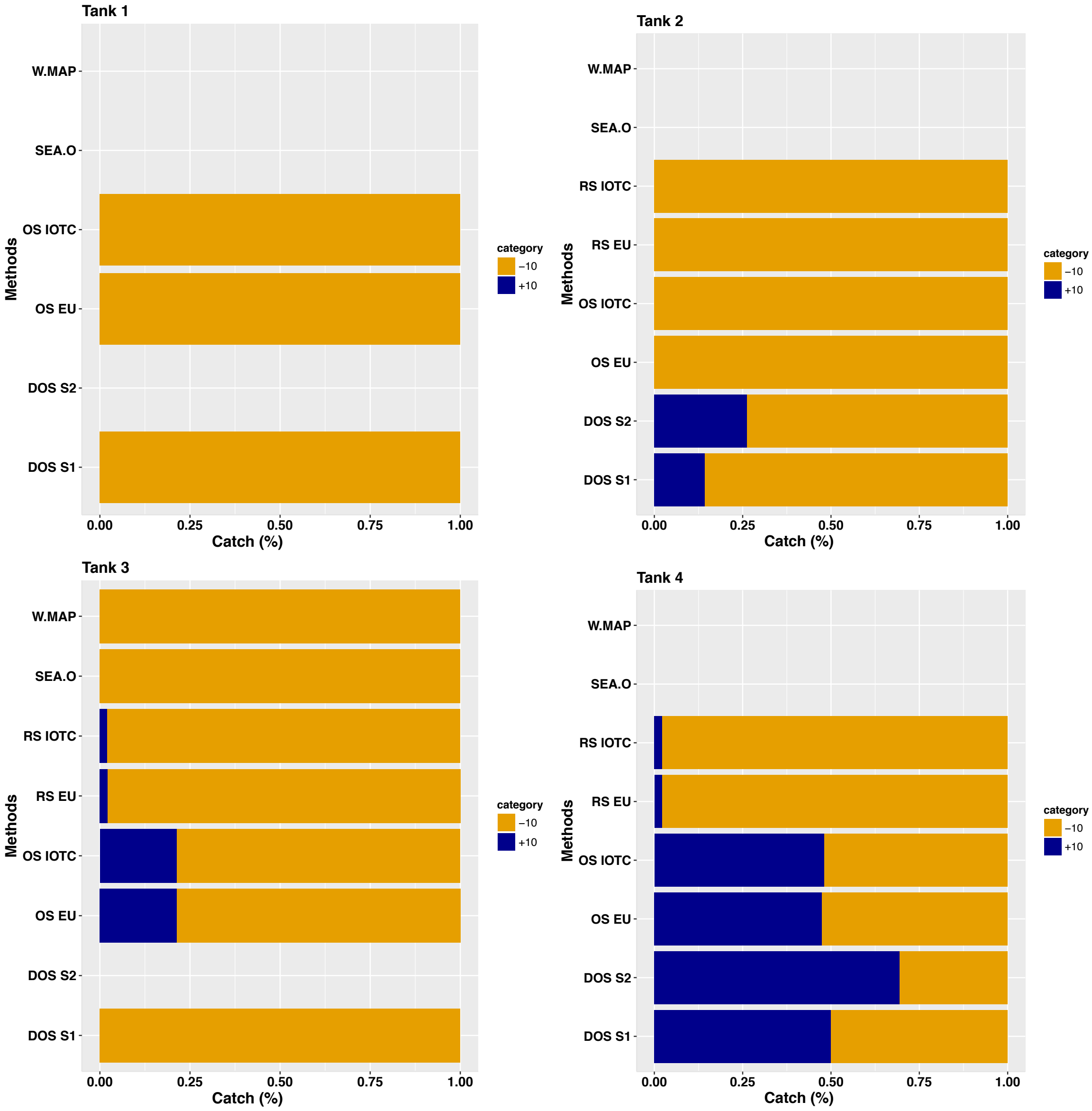
Tank 4	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	W.MAP
DOS S1								
DOS S2	3.142							
OS EU	0.468	5.970*						
OS IOTC	0.498	6.068*						
RS EU	24.2***	39.159***	19.55***					
RS IOTC	24.187***	39.14***		19.39***				
SEA.O	3.318	13.735***	1.157	1.105	14.562***	14.553***		
W.MAP	3.318	13.735***	1.157	1.105	14.562***	14.553***	0	

Tank 5	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	W.MAP
DOS S1								
DOS S2	27.812***							
OS EU	3.746*	11.143***						
OS IOTC	3.746*	11.143***						
RS EU	0.001	31.183***	4.277*					
RS IOTC	0.001	31.183***		4.277*				
SEA.O	2.741	33.99***	9.435***	9.435***	2.669	2.669		
W.MAP	2.741	33.99***	9.435***	9.435***	2.669	2.669		

Tank 6	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	W.MAP
DOS S1								
DOS S2	4.214*							
OS EU	8.072**	0.252						
OS IOTC	8.161**	0.269						
RS EU	25.749***	7.697**	6.882**					
RS IOTC	25.869***	7.770**		6.849*				
SEA.O	29.925***	14.515***	13.477***	13.384***	4.919*	4.883*		
W.MAP	29.925***	14.515***	13.477***	13.384***	4.919*	4.883*		

Tank 7	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	W.MAP
DOS S1								
DOS S2								
OS EU		0.394						
OS IOTC		0.394						
RS EU		0.472	0.001					
RS IOTC		0.472		0.001				
SEA.O		1.012	2.790	2.790	3.693*	3.693*		
W.MAP		1.012	2.790	2.790	3.693*	3.693*	0	

Tank 8	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	W.MAP
DOS S1								
DOS S2	1.689							
OS EU	7.805**	1.786						
OS IOTC	7.749**	1.761						
RS EU	0.659	4.118*	12.111***					
RS IOTC	0.669	4.146		12.101***				
SEA.O								
W.MAP	0.188	2.404	8.019**	7.97**	0.088	0.091		


Tank 1
W.MAP
SEA.O
OS IOTC
OS EU
DOS S2
DOS S1
Methods
0.00
0.25
0.50
0.75
1.00
Catch (%)
category
−10
+10
Tank 2
W.MAP
SEA.O
RS IOTC
RS EU
OS IOTC
OS EU
DOS S2
DOS S1
Methods
Catch (%)
category
−10
+10
Tank 3
W.MAP
SEA.O
RS IOTC
RS EU
OS IOTC
OS EU
DOS S2
DOS S1
Methods
Catch (%)
category
−10
+10
Tank 4
W.MAP
SEA.O
RS IOTC
RS EU
OS IOTC
OS EU
DOS S2
DOS S1
Methods
Catch (%)
category
−10
+10

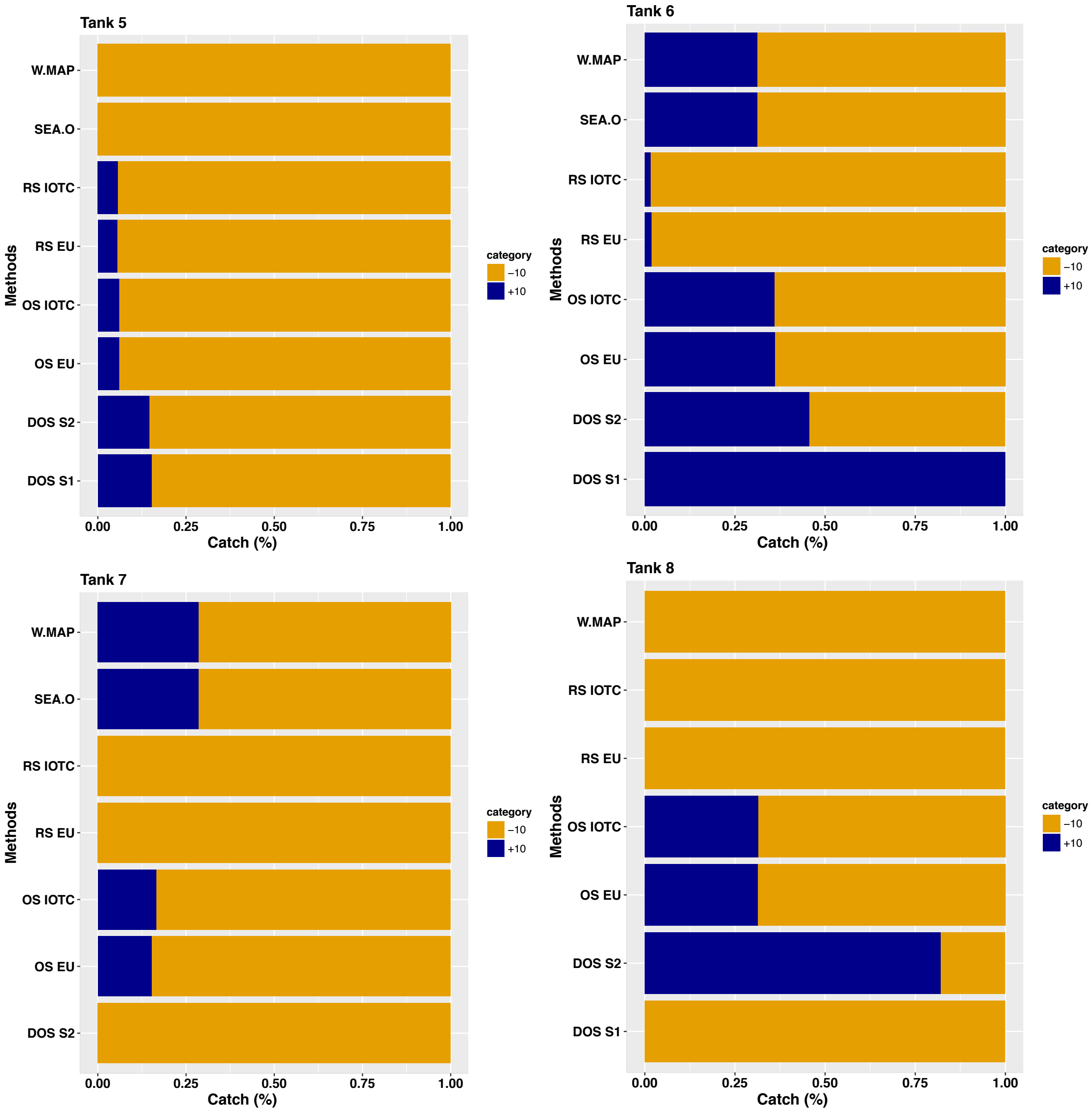


Figure 143: Proportion of bigeye tuna (BET) by commercial size category in the catch estimated by each method (DOS EMS S1 (DOS S1), DOS EMS S2 (DOS S2), Oversampling EU (OS EU), Oversampling IOTC (OS IOTC), Regular sampling EU (RS EU), Regular sampling IOTC (RS IOTC), Scientific Observer Programme (Sea. O), SFA EMS (SFA) and Well-map (W.MAP) for each sampled fish tank (1 to 8).

Table 164: Results of chi-square test for proportion of bigeye tuna (BET) by commercial size category in the catch estimated by each method (DOS EMS S1 (DOS S1), DOS EMS S2 (DOS S2), Oversampling EU (OS EU), Oversampling IOTC (OS IOTC), Regular sampling EU (RS EU), Regular sampling IOTC (RS IOTC), Scientific Observer Programme (Sea. O) and Well-map (W.MAP) for each sampled fish tank (2 to 8). Levels of significance were *p < 0.05, **p < 0.01 and ***p < 0.001). Yellow boxes indicate no data available for analysis. Grey boxes indicate no analysis performed between two variables.

Tank 2	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	W.MAP
DOS S1								
DOS S2	0.349							
OS EU	0.613	1.262*						
OS IOTC	0.568	1.171*						
RS EU	0.749	1.531						
RS IOTC	0.689	1.412						
SEA.O								
W.MAP								

Tank 3	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	W.MAP
DOS S1								
DOS S2								
OS EU	0.053							
OS IOTC	0.054							
RS EU	0.004		0.575					
RS IOTC	0.004			0.534				
SEA.O			1.159***	1.161***	0.108***	0.102		
W.MAP			1.812***	1.815***	0.172***	0.163		

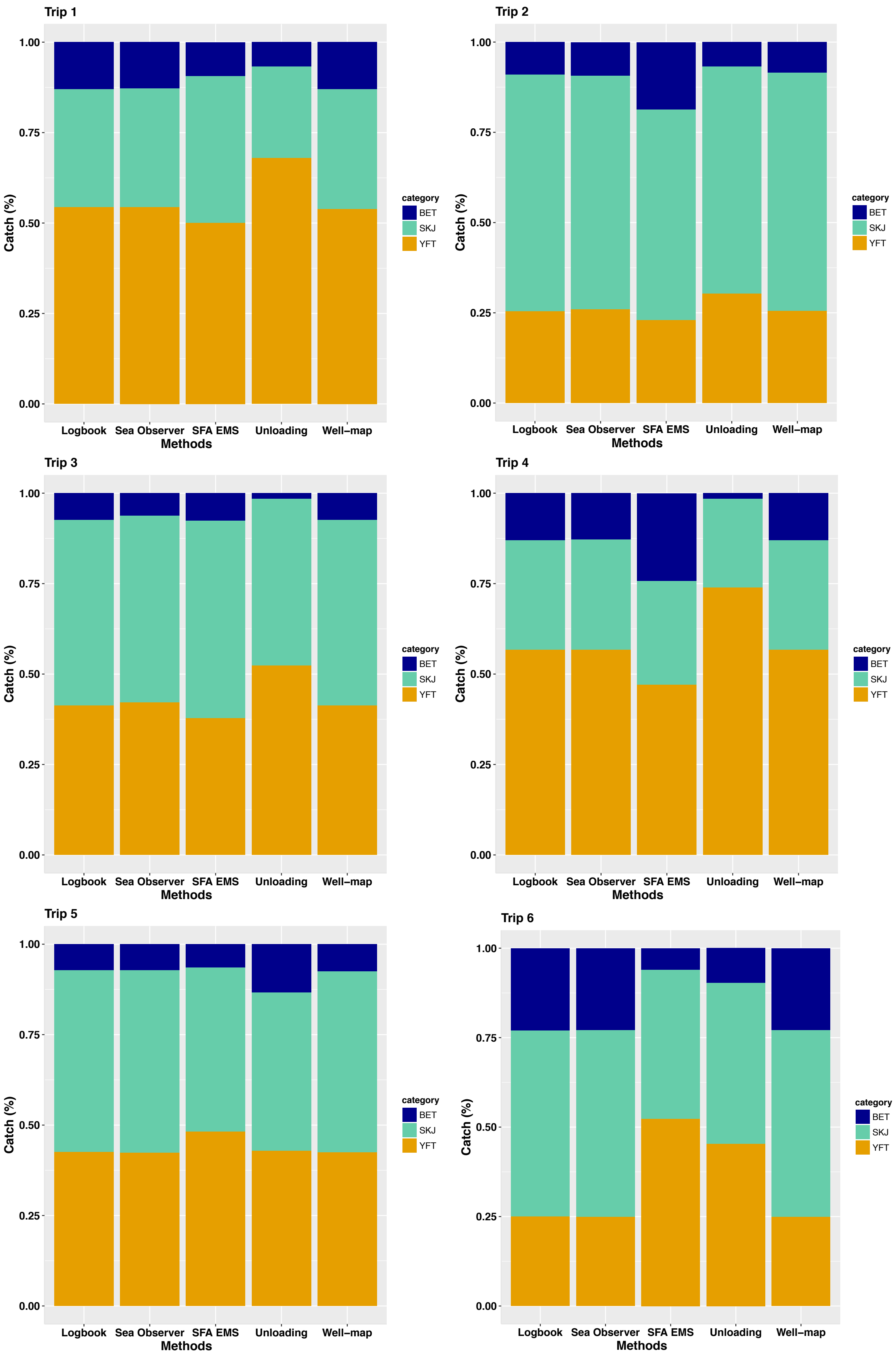
Tank 4	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	W.MAP
DOS S1								
DOS S2	0.207							
OS EU	0.004	0.438						
OS IOTC	0.002	0.399						
RS EU	2.557	4.672***	2.969***					
RS IOTC	2.357	4.339***		2.744				
SEA.O								
W.MAP								

Tank 5	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	W.MAP
DOS S1								
DOS S2	0.001							
OS EU	0.380	0.213						
OS IOTC	0.355	0.204						
RS EU	1.046	0.405	0.003					
RS IOTC	0.963	0.380		0.002				
SEA.O	2.485	2.268***	0.937***	0.934***	0.871	0.889		
W.MAP	2.485	2.268***	0.937***	0.934***	0.871	0.889		

Tank 6	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	W.MAP
DOS S1								
DOS S2	4.64***							
OS EU	7.116*	0.101						
OS IOTC	6.988**	0.101						
RS EU	9.401***	1.476	1.188					
RS IOTC	9.233***	1.397		1.105				
SEA.O	9.224**	0.268	0.064	0.057	0.993	0.935		
W.MAP	9.224**	0.268	0.064	0.057	0.993	0.935	0	

Tank 7	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	W.MAP
DOS S1								
DOS S2								
OS EU		0.433						
OS IOTC		0.471						
RS EU			1.046***					
RS IOTC				1.043***				
SEA.O		0.938	0.176	0.133	2.180	2.014		
W.MAP		0.938	0.176	0.133	2.180	2.014	0	

Tank 8	DOS S1	DOS S2	OS EU	OS IOTC	RS EU	RS IOTC	SEA.O	W.MAP
DOS S1								
DOS S2	1.946***							
OS EU	0.226	8.309**						
OS IOTC	0.227	8.004**						
RS EU		21.215***	6.47*					
RS IOTC		19.902***		5.926**				
SEA.O								
W.MAP		8.635**	1.711*	1.711*				


Trip 1
Trip 2
Trip 3
Trip 4
Trip 5
Trip 6
Catch (%)
1.00
0.75
0.50
0.25
0.00
Logbook
Sea Observer
SFA EMS
Unloading
Well−map
Methods
category
BET
SKJ
YFT

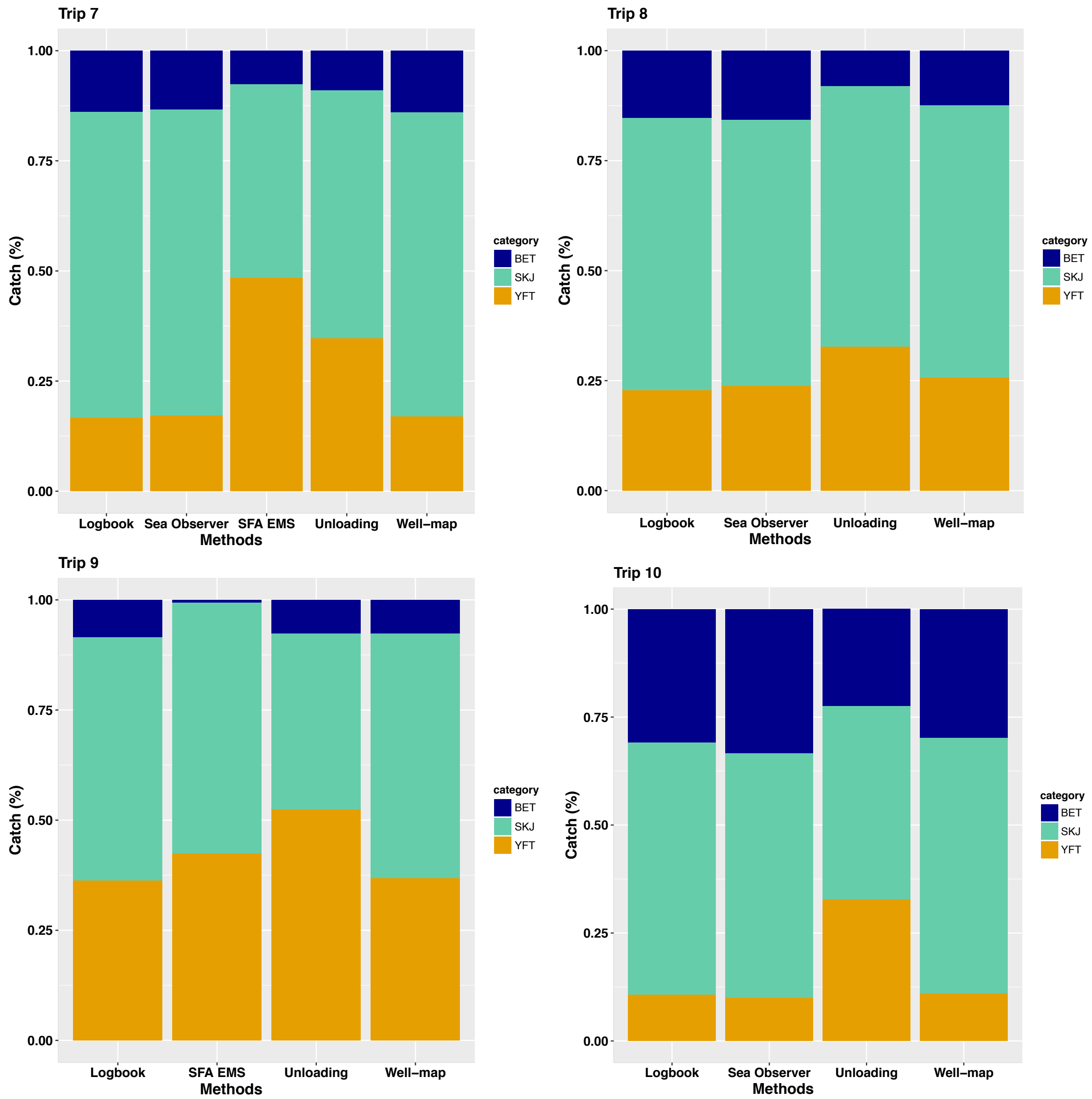


Figure 144: Proportion of tuna by in the catch estimated by each method (Logbook, Scientific Observer Programme (Sea Observer), Unloading and Well-map) for each sampled fishing trips (1-10).

Table 165: Results of chi-square test for proportion of tuna by species in the catch estimated by each method (Logbook, Scientific Observer Programme (S. Observer) Unloading and Well-map) for each sampled fishing trip (1-10). Levels of significance were *p < 0.05, **p < 0.01 and ***p < 0.001). Yellow boxes indicate no data available for analysis.

Trip 1	Logbook	S.Observer	SFA EMS	Unloading	Well-map
Logbook					
S.Observer	0.025				
SFA EMS	14.36***	13.269**			
Unloading	40.545***	40.181***	60.22***		
Well-map	0.069	0.049	12.896**	43.051***	

Trip 2	Logbook	S.Observer	SFA EMS	Unloading	Well-map
Logbook					
S.Observer	0.173				
SFA EMS	50.849***	47.317***			
Unloading	12.305**	11.388**	93.647***		
Well-map	0.285	0.665	54.531***	9.486**	

Trip 3	Logbook	S.Observer	SFA EMS	Unloading	Well-map
Logbook					
S.Observer	1.569				
SFA EMS	3.271	5.859			
Unloading	82.455***	64.41***	98.679***		
Well-map	0	1.569	3.271	82.455***	

Trip 4	Logbook	S.Observer	SFA EMS	Unloading	Well-map
Logbook					
S.Observer	0.028				
SFA EMS	39.072***	40.788***			
Unloading	122.34***	120.53***	252.46***		
Well-map	0	0.028	39.072***	122.34***	

Trip 5	Logbook	S.Observer	SFA EMS	Unloading	Well-map
Logbook					
S.Observer	0.004				
SFA EMS	5.091	5.357			
Unloading	18.266***	18.289***	21.759***		
Well-map	0.064	0.064	5.288	16.351***	

Trip 6	Logbook	S.Observer	SFA EMS	Unloading	Well-map
Logbook					
S.Observer	0.006				
SFA EMS	285.01***	288.46***			
Unloading	188.6***	191.17***	21.096***		
Well-map	0.006	0	288.46***	191.17***	

Trip 7	Logbook	S.Observer	SFA EMS	Unloading	Well-map
Logbook					
S.Observer	0.119				
SFA EMS	159.18***	159.02***			
Unloading	66.246***	64.25***	27.573***		
Well-map	0.022	0.110	163.88***	67.682***	

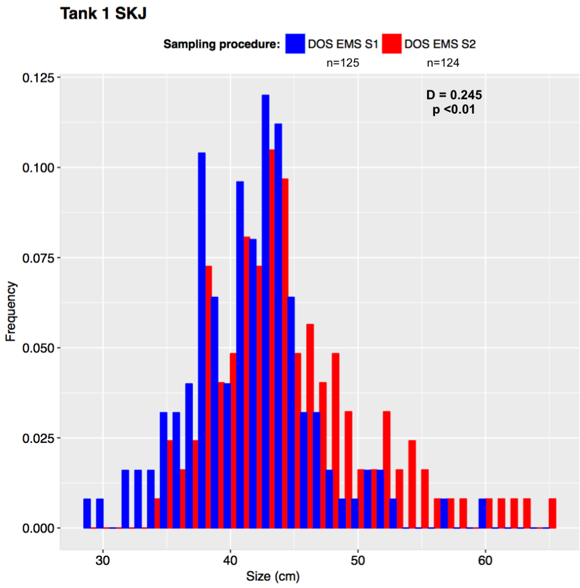
Trip 8	Logbook	S.Observer	SFA EMS	Unloading	Well-map
Logbook					
S.Observer	0.307				
SFA EMS					
Unloading	31.301***	29.817***			
Well-map	3.706	3.828		14.078***	

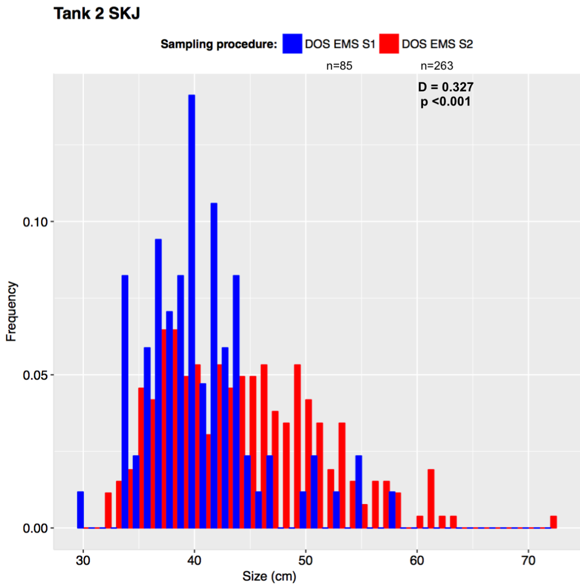
Trip 9	Logbook	S.Observer	SFA EMS	Unloading	Well-map
Logbook					
S.Observer					
SFA EMS	35.251***				
Unloading	26.687***		48.062***		
Well-map	0.232		30.848***	25.594***	

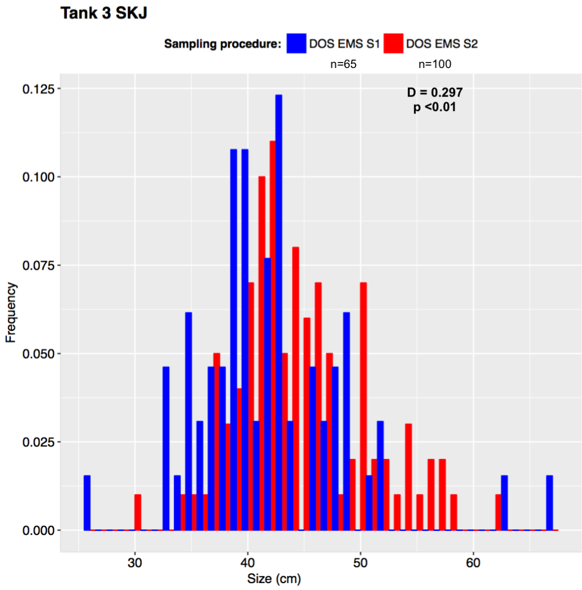
Trip 10	Logbook	S.Observer	SFA EMS	Unloading	Well-map
Logbook					
S.Observer	1.103				
SFA EMS					
Unloading	102.38***	109.66***			
Well-map	0.192	2.193		98.676***	

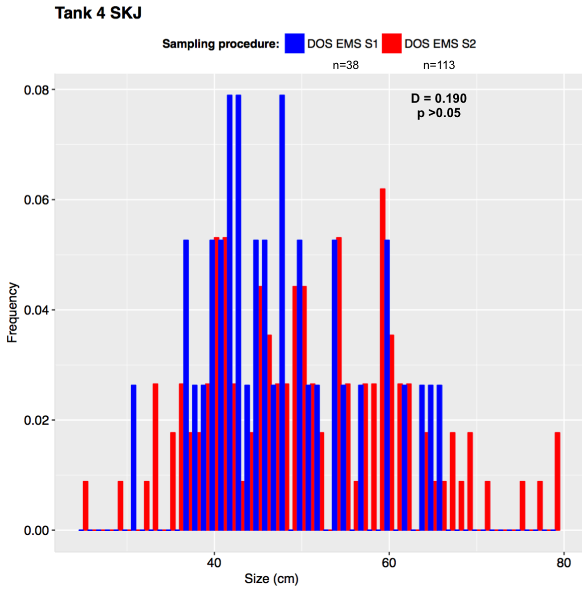
7.5 Comparison of Fish Size Distributions for Retained Tuna

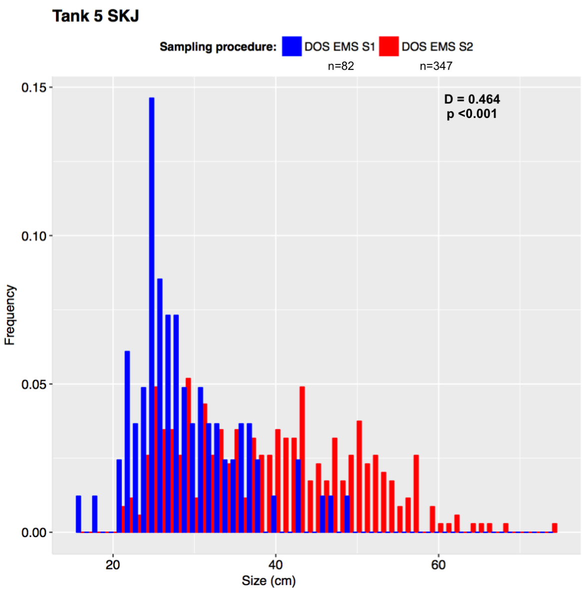
Comparison between DOS EMS Sampling one and DOS EMS Sampling two

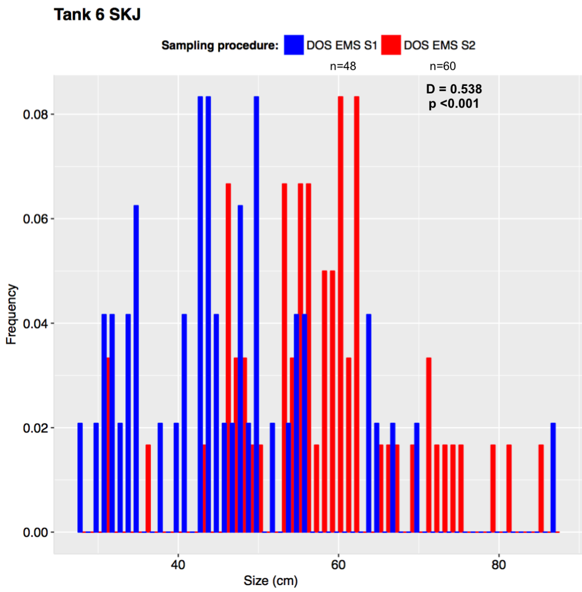

Tank 1 SKJ
Sampling procedure: DOS EMS S1 DOS EMS S2
n=125 n=124
D = 0.245
p <0.01
Frequency
Size (cm)


Tank 2 SKJ
Sampling procedure: DOS EMS S1 DOS EMS S2
n=85 n=263
D = 0.327
p <0.001
Frequency
Size (cm)


Tank 3 SKJ
Sampling procedure: DOS EMS S1 DOS EMS S2
n=65 n=100
D = 0.297
p <0.01
Frequency
Size (cm)


Tank 4 SKJ
Sampling procedure: DOS EMS S1 DOS EMS S2
n=38 n=113
D = 0.190
p >0.05
Frequency
Size (cm)


Tank 5 SKJ
Sampling procedure: DOS EMS S1 DOS EMS S2
n=82 n=347
D = 0.464
p <0.001
Frequency
Size (cm)


Tank 6 SKJ
Sampling procedure: DOS EMS S1 DOS EMS S2
n=48 n=60
D = 0.538
p <0.001
Frequency
Size (cm)

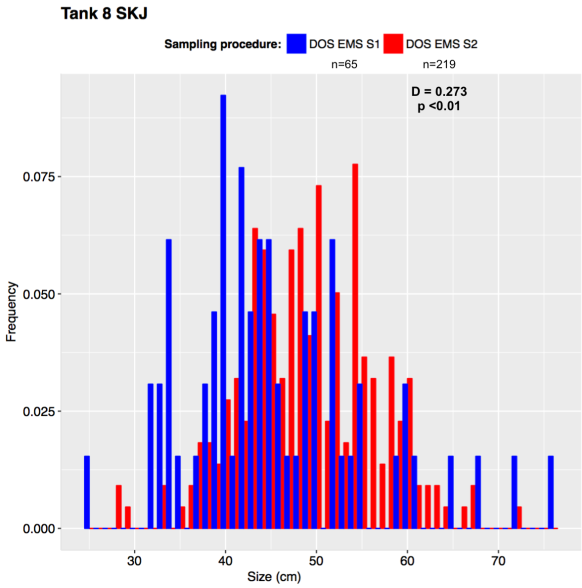
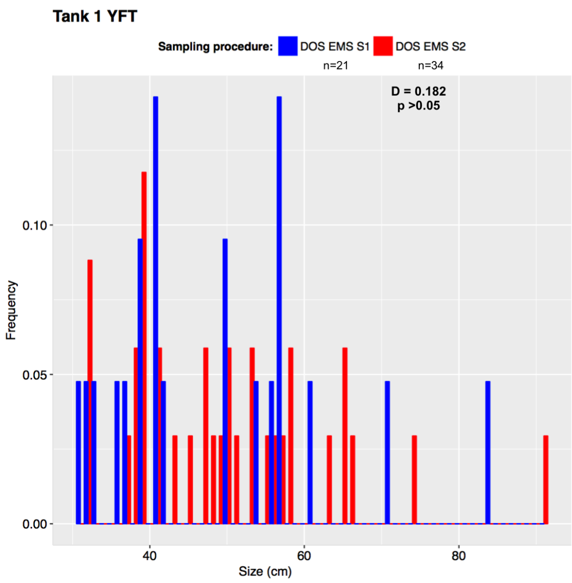
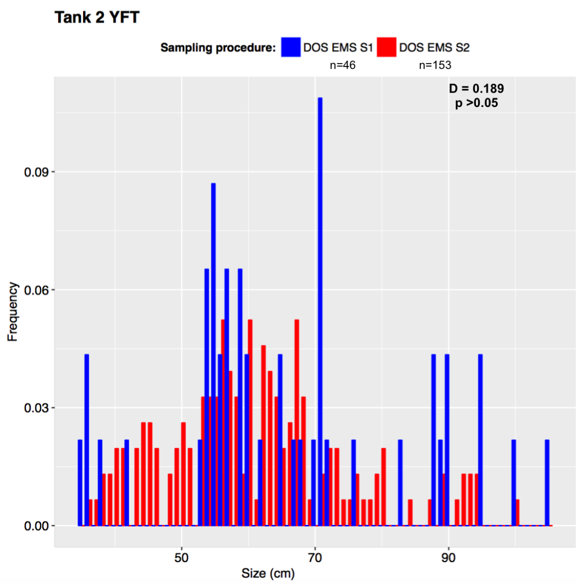


Figure 145: Size frequency histograms of skipjack tuna (SKJ) by tank for DOS EMS S1 (R1) and DOS EMS S2 (R2) procedures. n indicates the number of individuals measured by each procedure. D statistic and P-value of the Kolmogorov-Smirnov test are indicated.





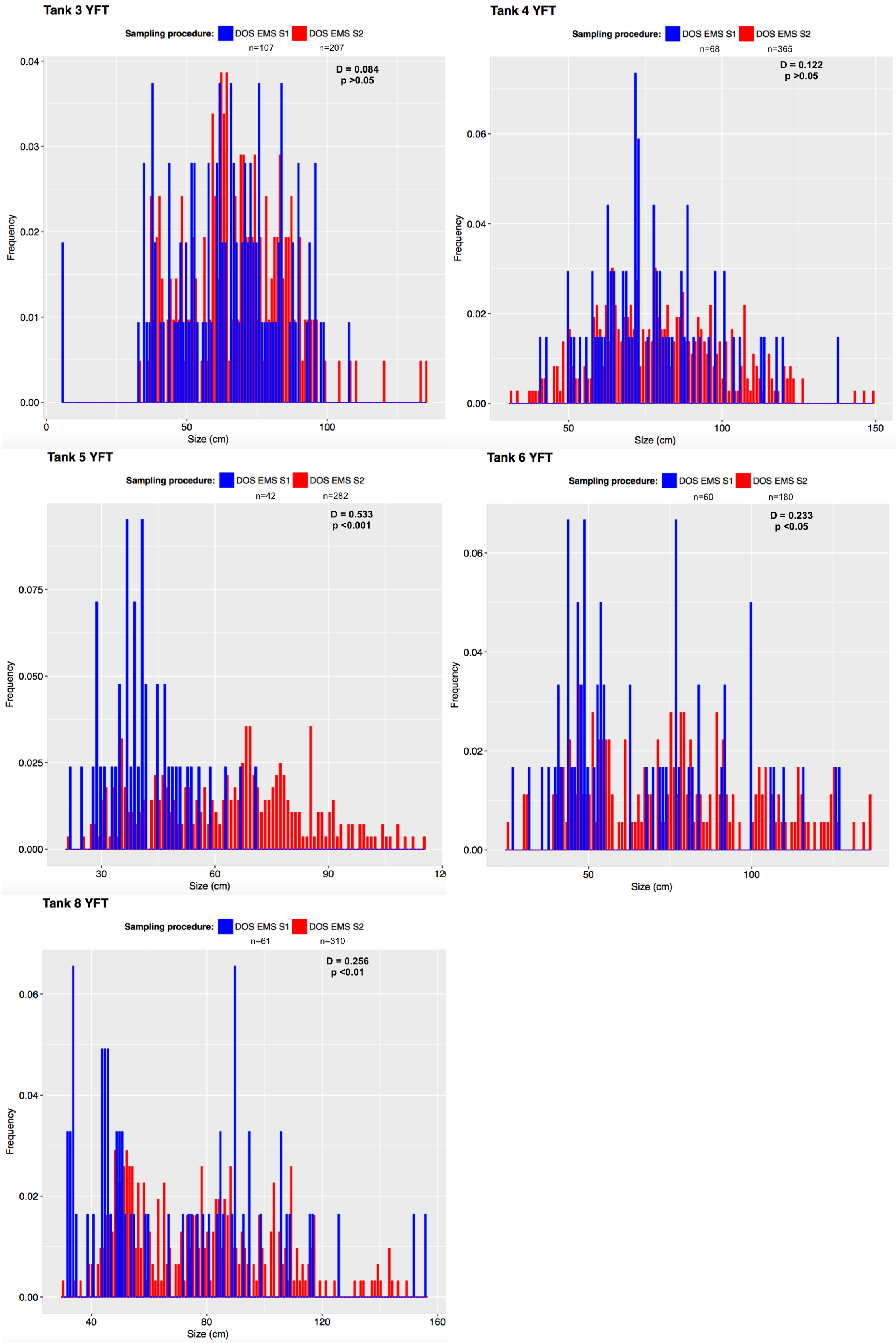


Figure 146: Size frequency histograms of yellowfin tuna (YFT) by tank for DOS EMS S1 (R1) and DOS EMS S2 (R2) procedures. n indicates the number of individuals measured by each procedure. D statistic and P-value of the Kolmogorov-Smirnov test are indicated.

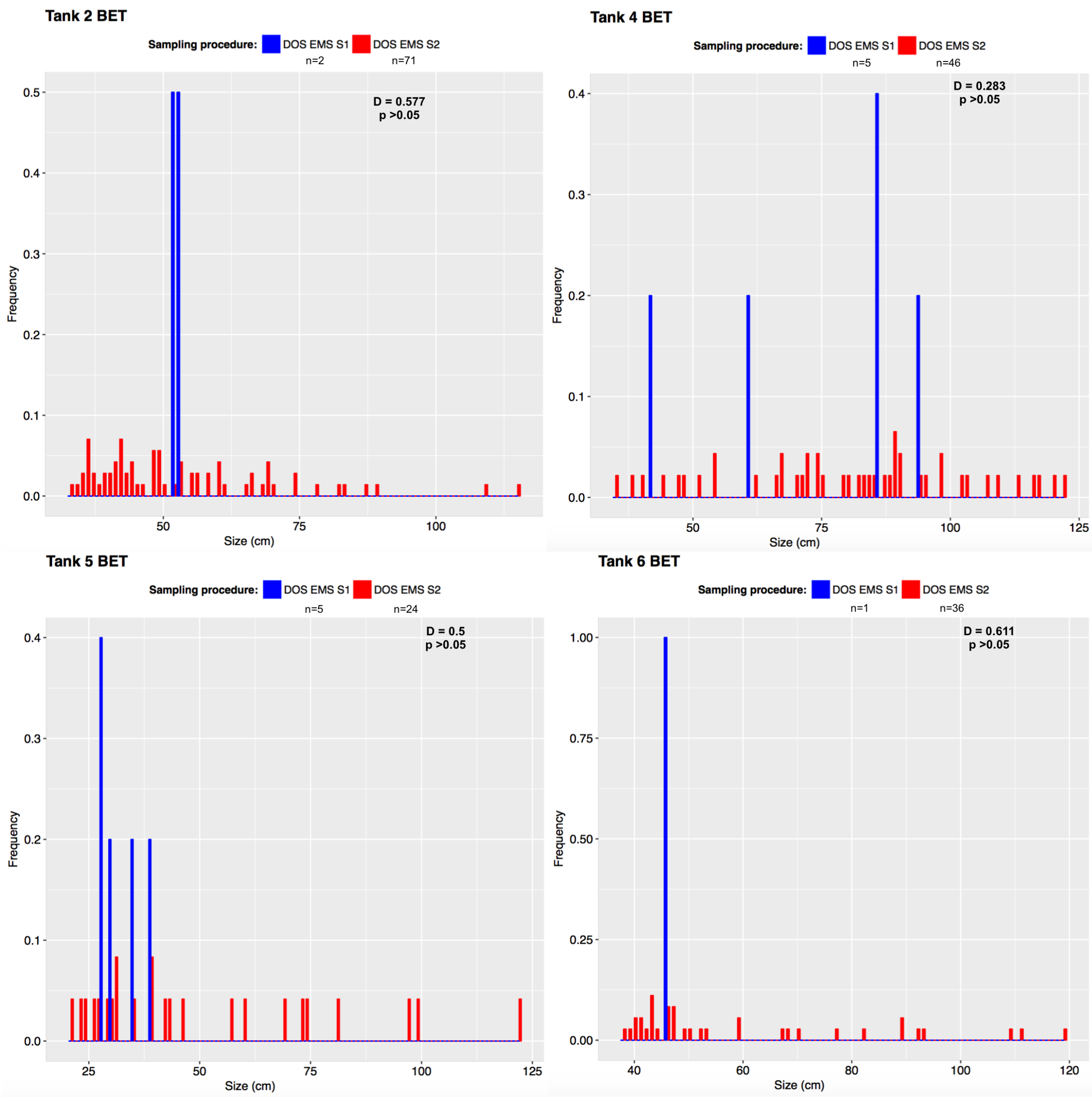
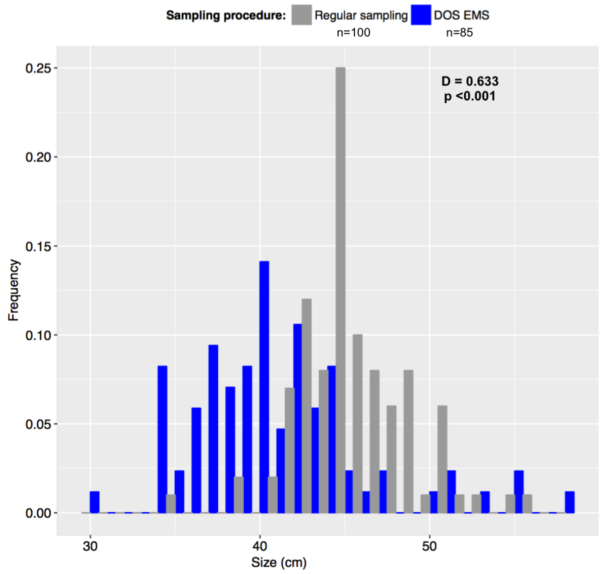


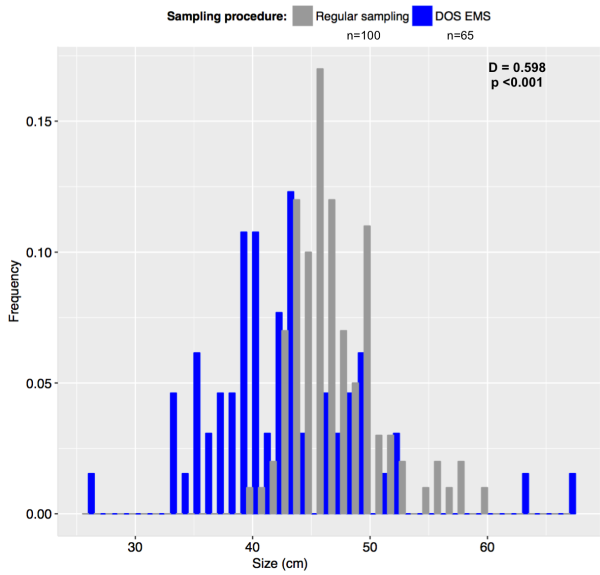
Figure 147: Size frequency histograms of bigeye tuna (BET) by tank for DOS EMS S1 (R1) and DOS EMS S2 (R2) procedures. n indicates the number of individuals measured by each procedure. D statistic and P-value of the Kolmogorov-Smirnov test are indicated.

Comparison between Regular sampling and DOS EMS S1

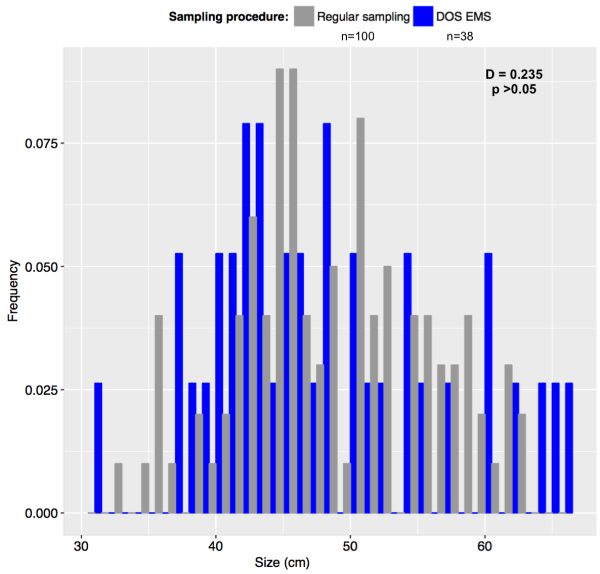
Tank 2 SKJ



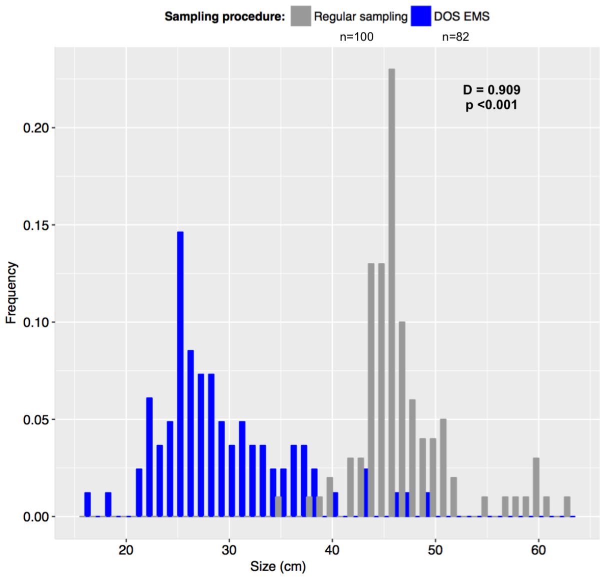
Tank 3 SKJ



Tank 4 SKJ



Tank 5 SKJ



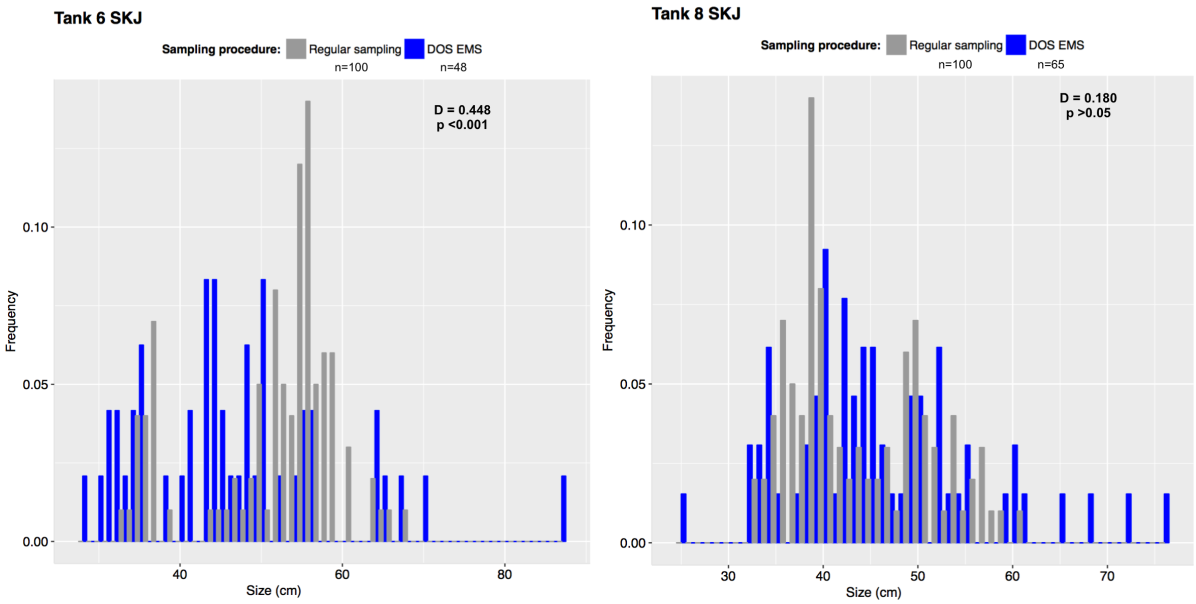
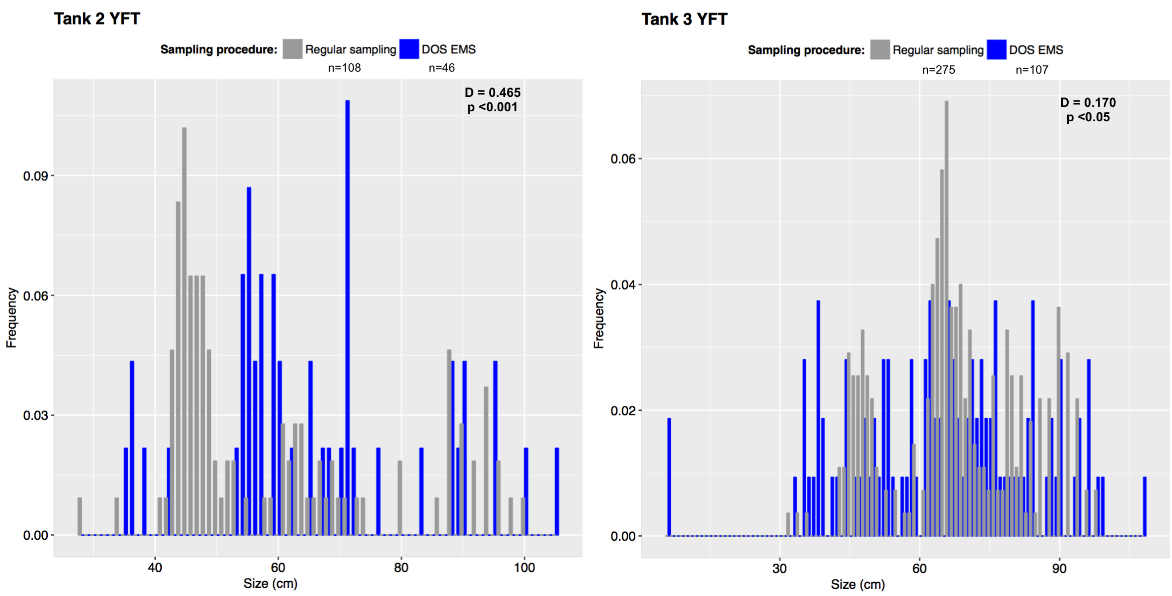


Figure 148: Size frequency histograms of skipjack tuna (SKJ) by tank for Regular sampling and DOS EMS S1 procedures. n indicates the number of individuals measured by each procedure. D statistic and P-value of the Kolmogorov-Smirnov test are indicated.



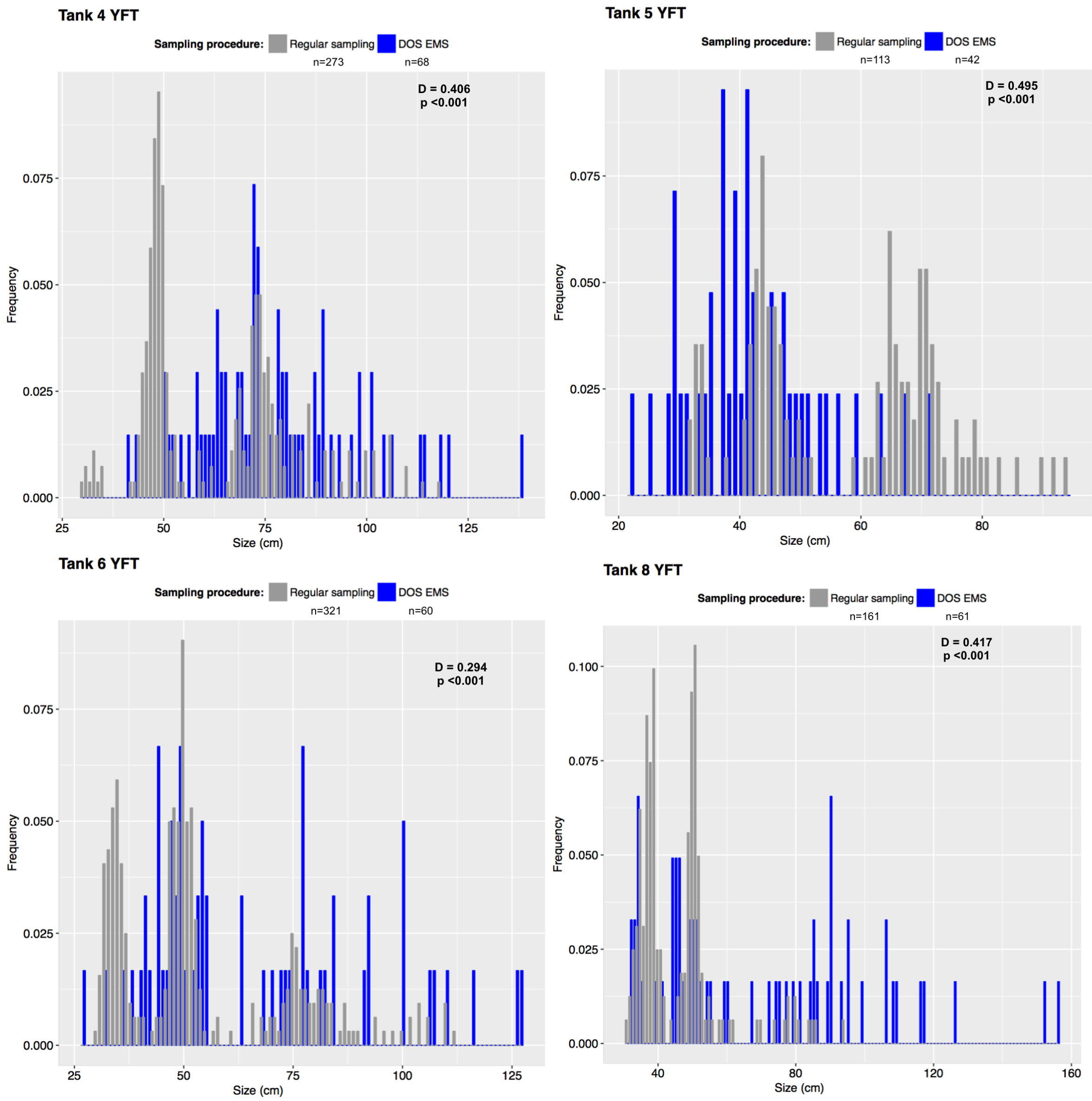


Figure 149: Size frequency histograms of yellowfin tuna (YFT) by tank for Regular sampling and DOS EMS S1 procedures. n indicates the number of individuals measured by each procedure. D statistic and P-value of the Kolmogorov-Smirnov test are indicated.

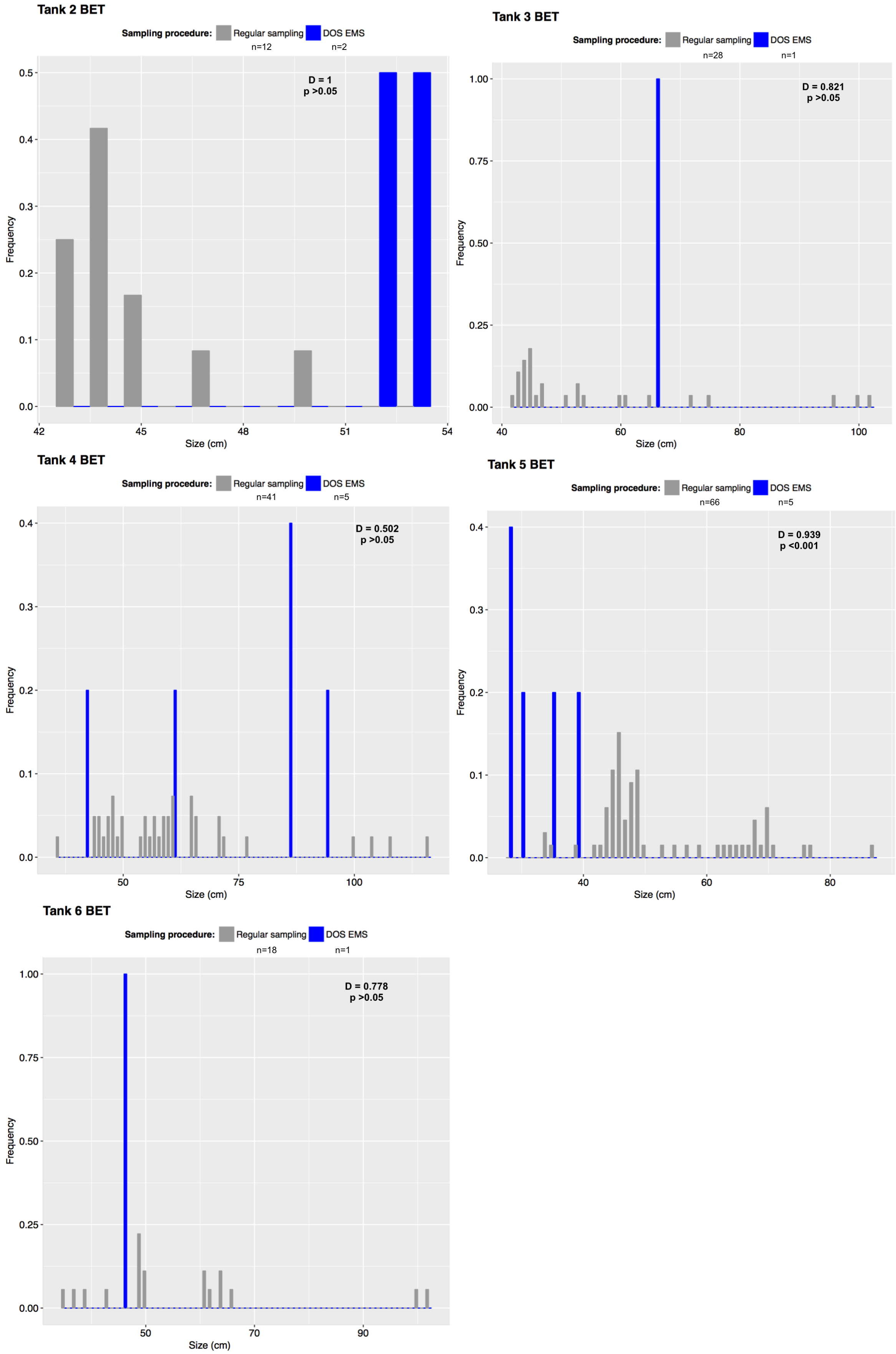
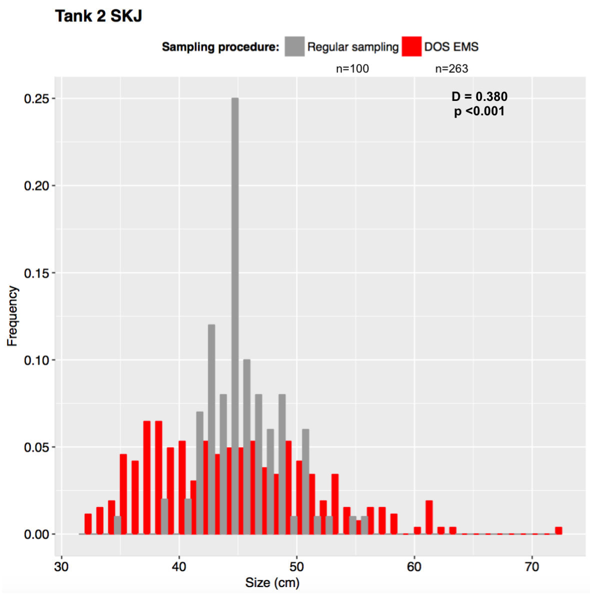
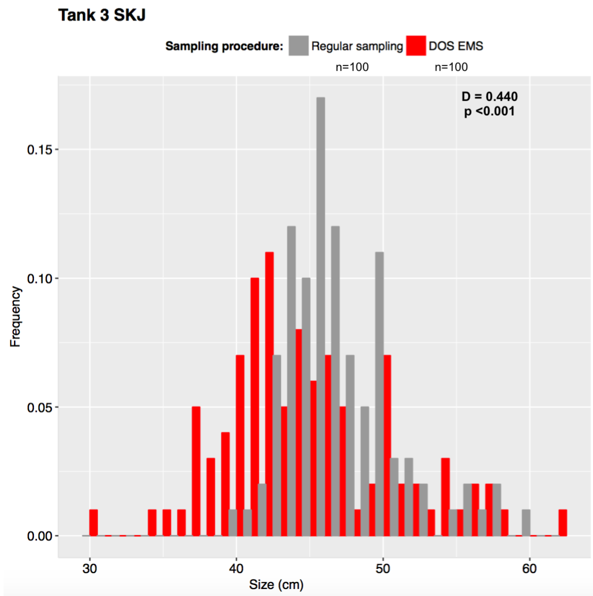
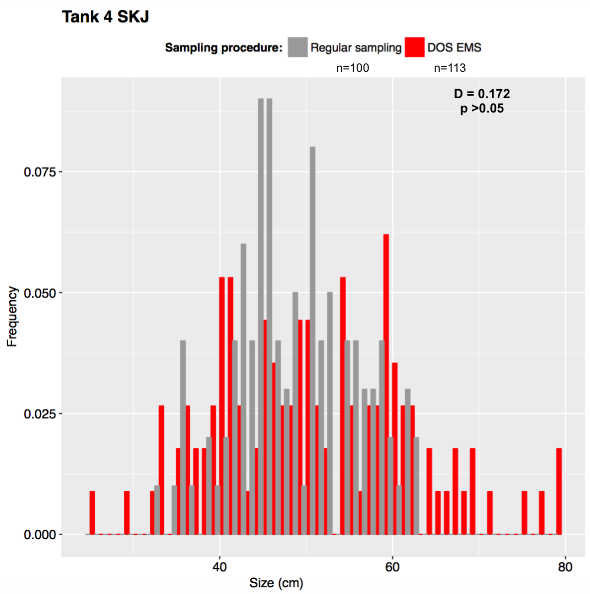


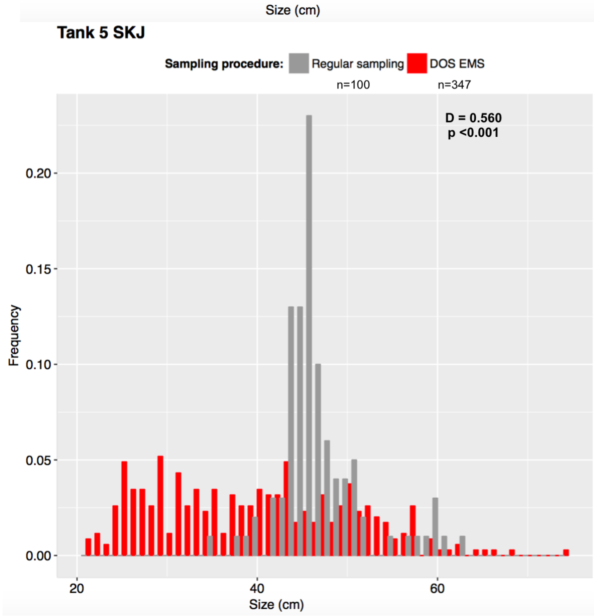
Figure 150: Size frequency histograms of bigeye tuna (BET) by tank for DOS EMS S1 and Regular sampling procedures. n indicates the number of individuals measured by each procedure. D statistic and P-value of the Kolmogorov-Smirnov test are indicated.

Comparison between Regular sampling and DOS EMS S2









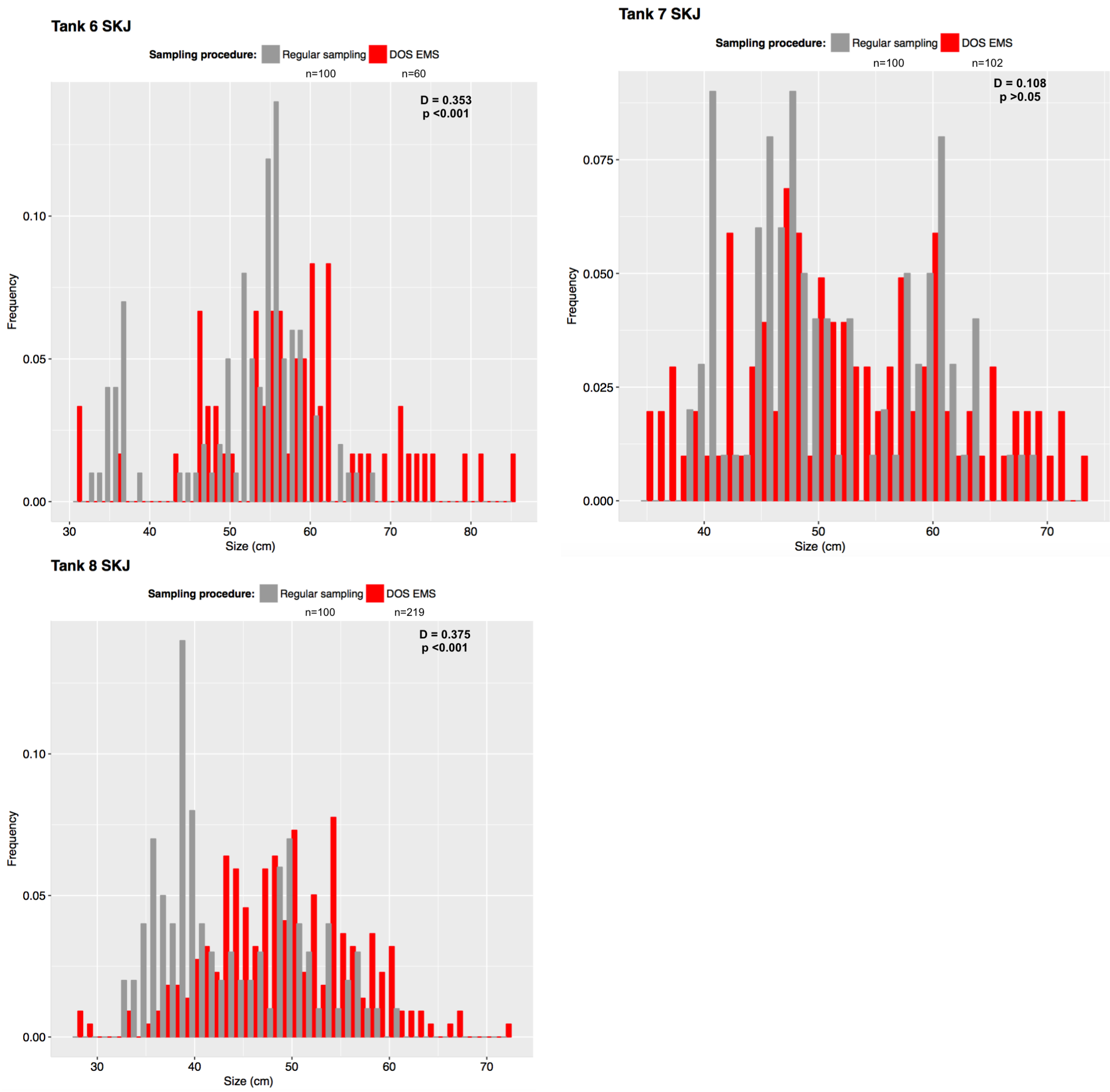
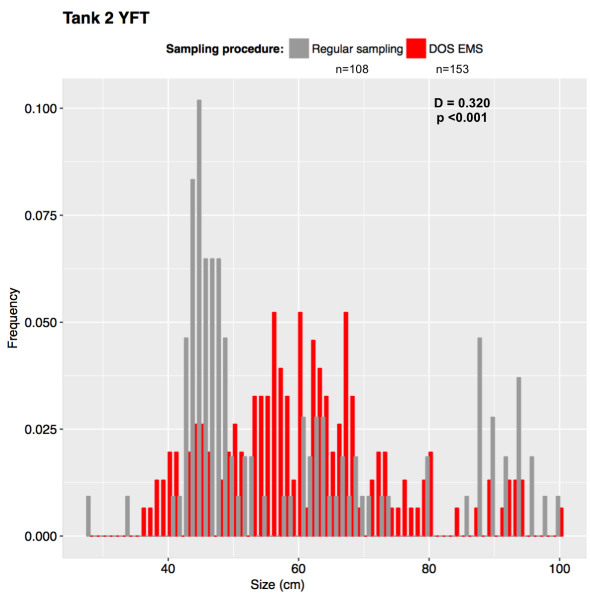
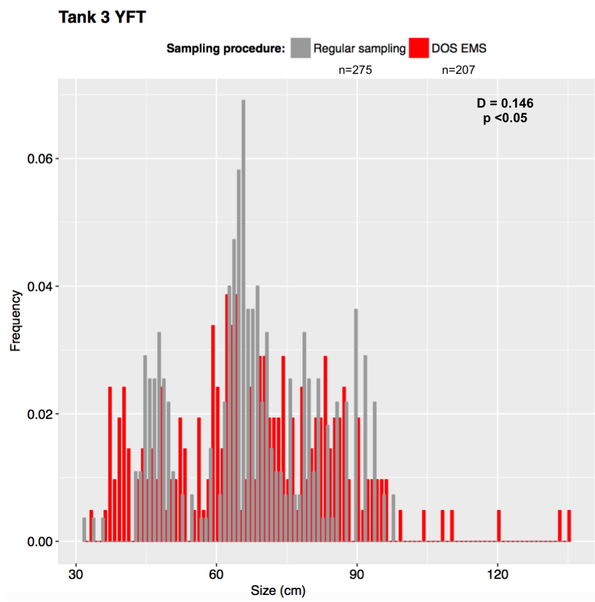
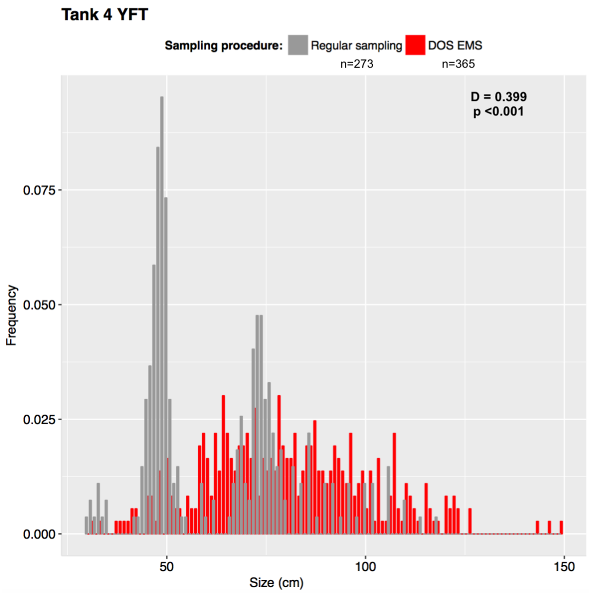
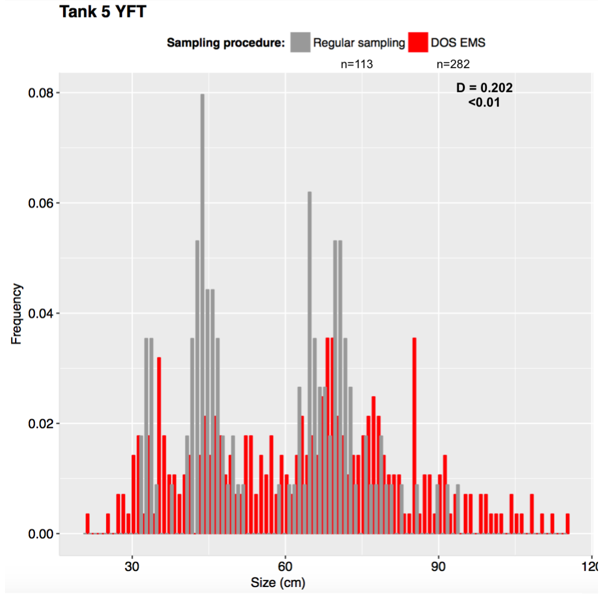


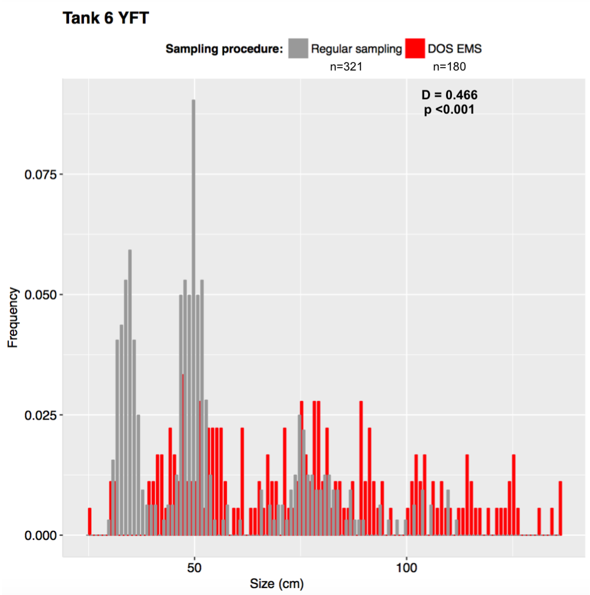
Figure 151: Size frequency histograms of skipjack tuna (SKJ) by tank for Regular sampling and DOS EMS S2 procedures. n indicates the number of individuals measured by each procedure. D statistic and P-value of the Kolmogorov-Smirnov test are indicated.

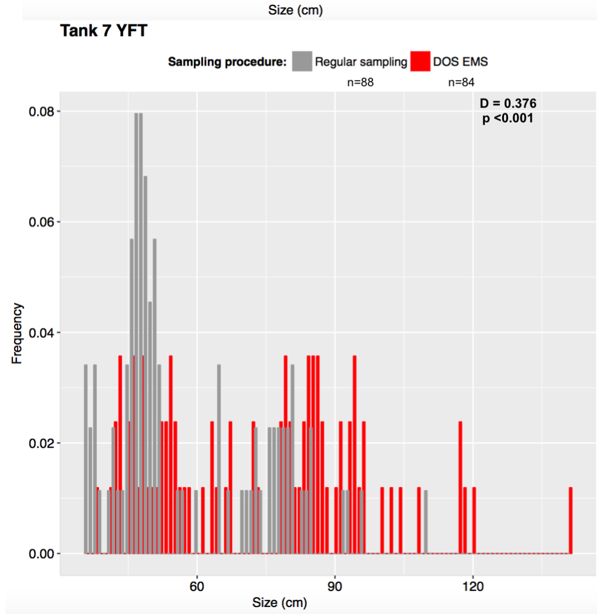

Tank 2 YFT
Sampling procedure: Regular sampling DOS EMS
n=108 n=153
D = 0.320
p <0.001
Frequency
Size (cm)


Tank 3 YFT
Sampling procedure: Regular sampling DOS EMS
n=275 n=207
D = 0.146
p <0.05
Frequency
Size (cm)


Tank 4 YFT
Sampling procedure: Regular sampling DOS EMS
n=273 n=365
D = 0.399
p <0.001
Frequency
Size (cm)


Tank 5 YFT
Sampling procedure: Regular sampling DOS EMS
n=113 n=282
D = 0.202
<0.01
Frequency
Size (cm)


Tank 6 YFT
Sampling procedure: Regular sampling DOS EMS
n=321 n=180
D = 0.466
p <0.001
Frequency
Size (cm)


Tank 7 YFT
Sampling procedure: Regular sampling DOS EMS
n=88 n=84
D = 0.376
p <0.001
Frequency
Size (cm)

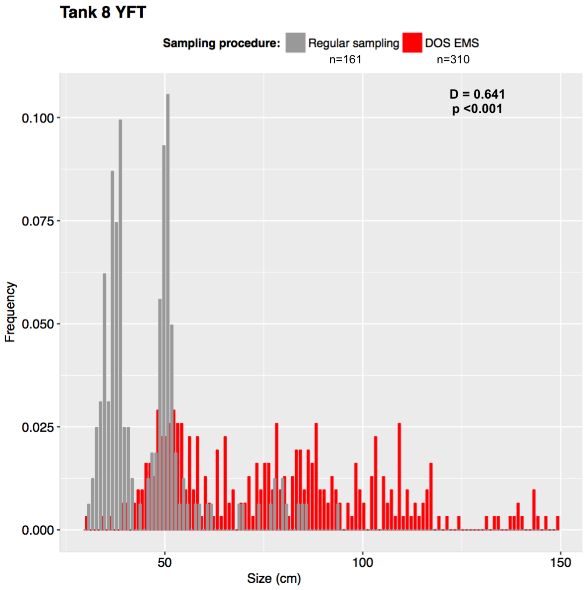
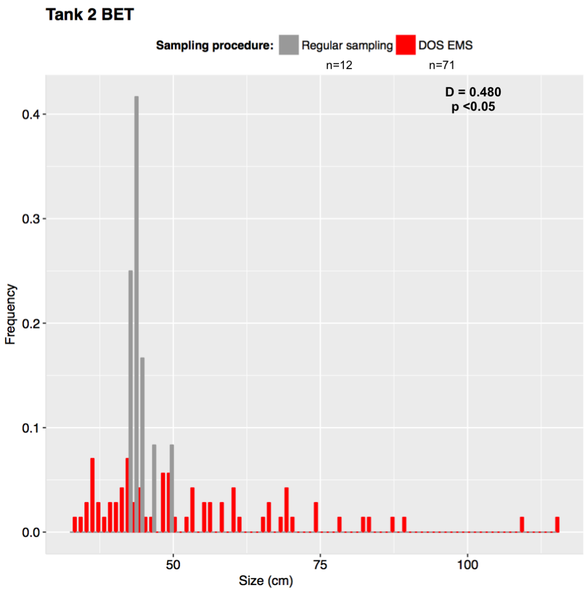
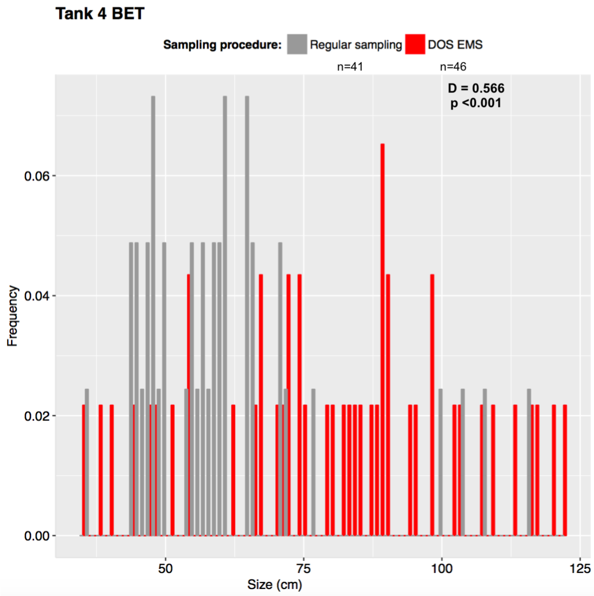


Figure 152: Size frequency histograms of yellowfin tuna (YFT) by tank for Regular sampling and DOS EMS S2 procedures. n indicates the number of individuals measured by each procedure. D statistic and P-value of the Kolmogorov-Smirnov test are indicated.





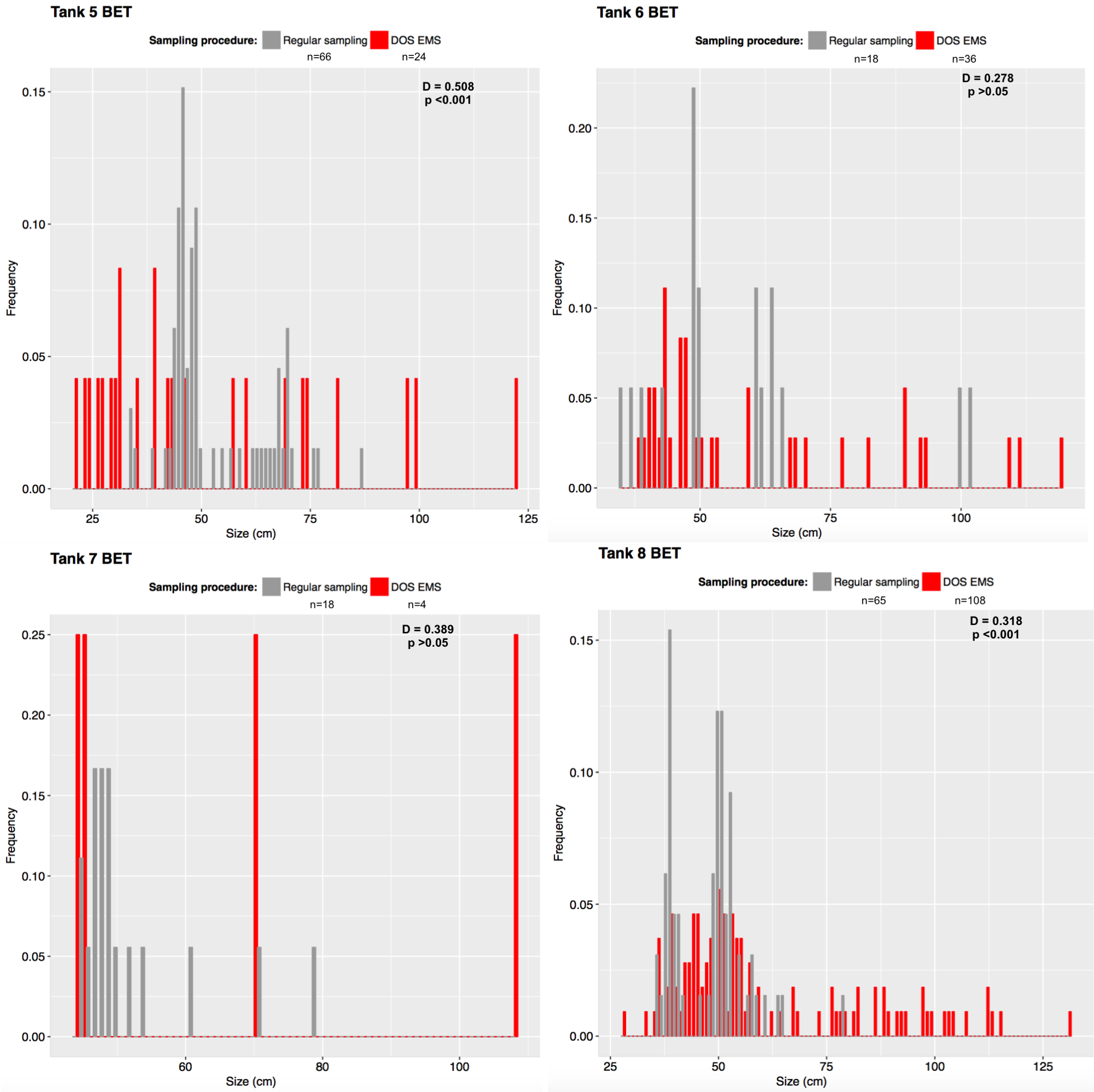
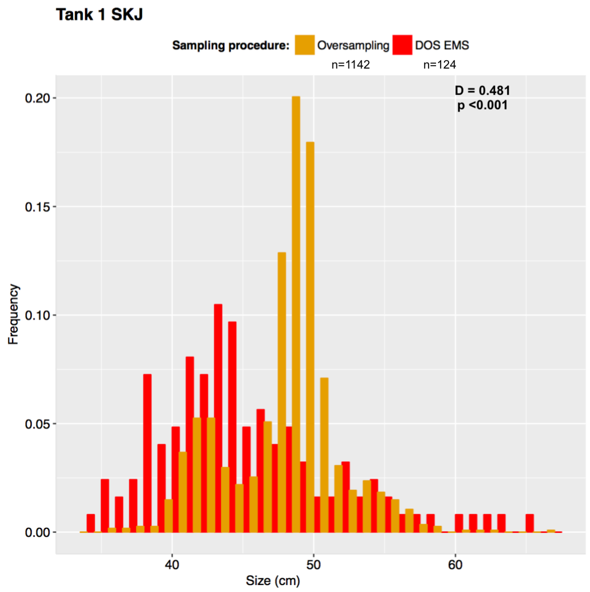
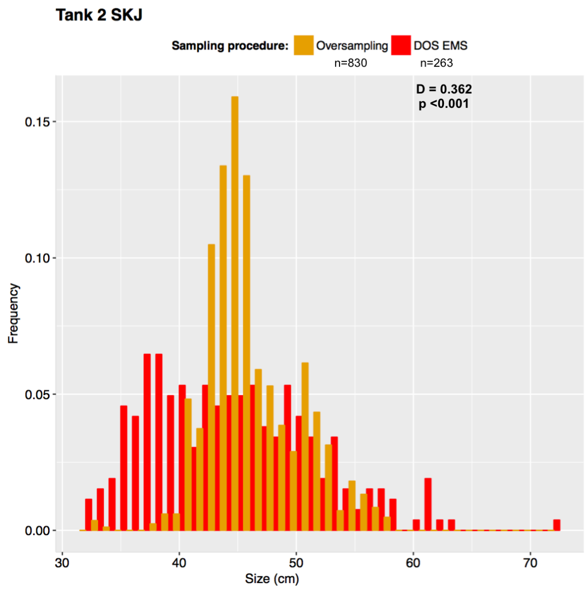
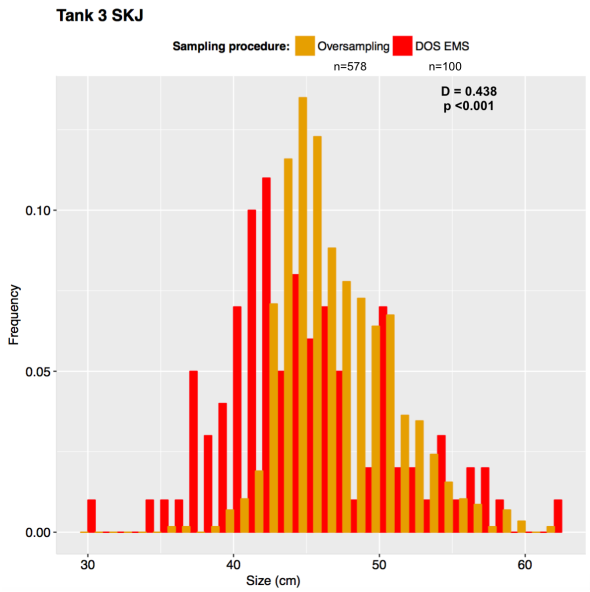


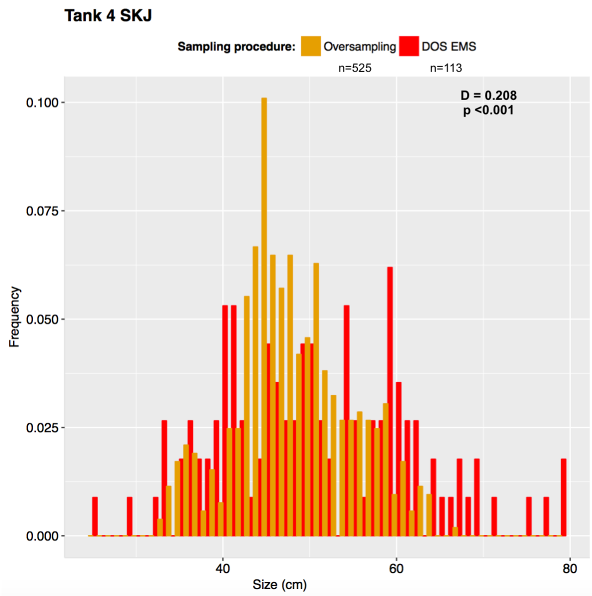
Figure 153: Size frequency histograms of bigeye tuna (BET) by tank for Regular sampling and DOS EMS S2 procedures. n indicates the number of individuals measured by each procedure. D statistic and P-value of the Kolmogorov-Smirnov test are indicated.

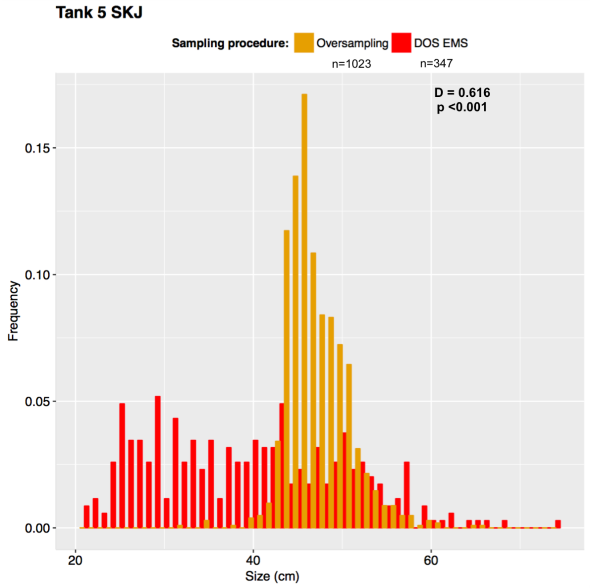
Comparison between Oversampling and DOS EMS S2

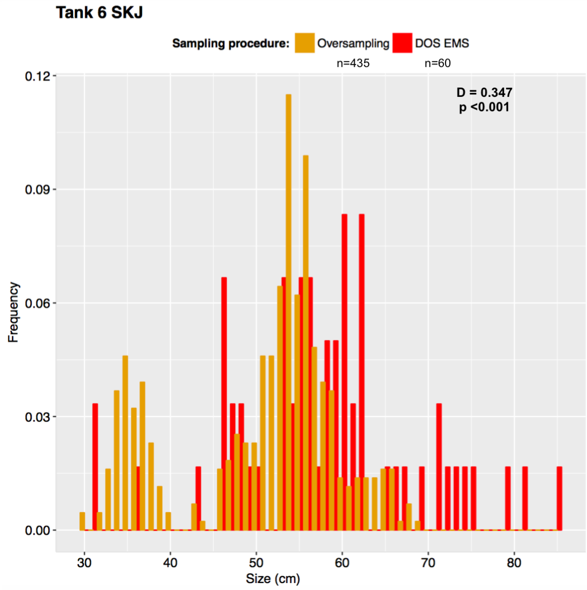












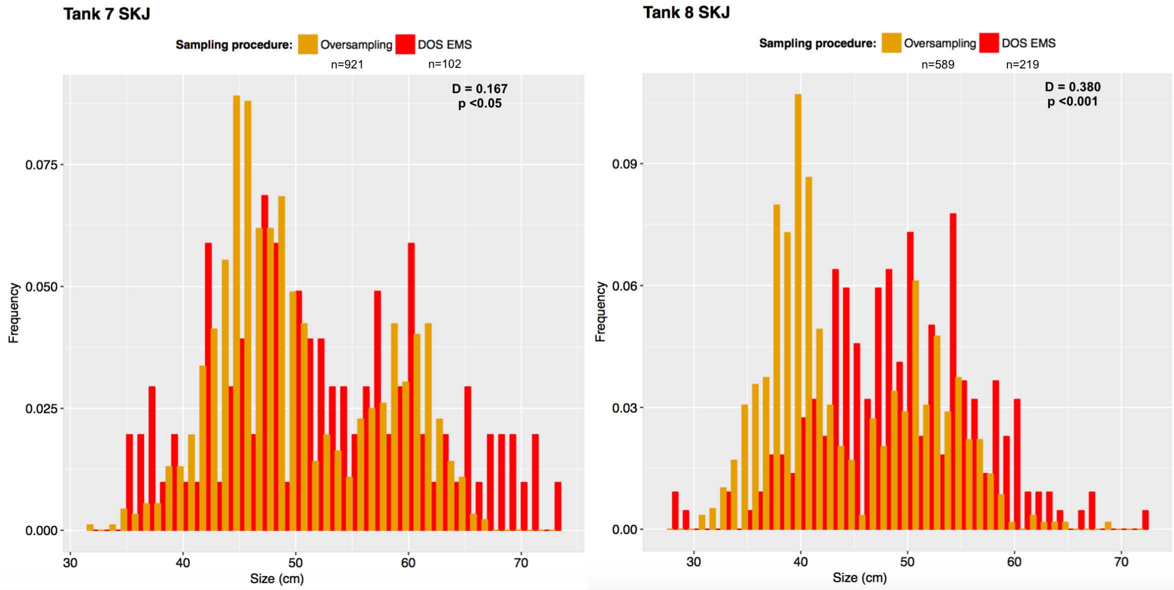
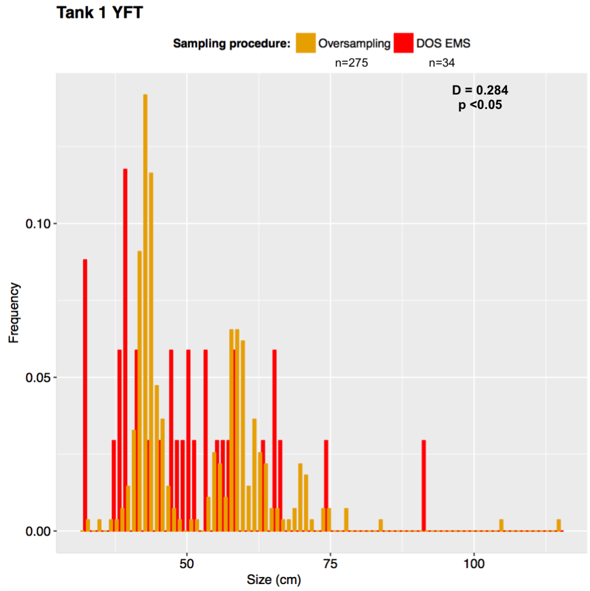
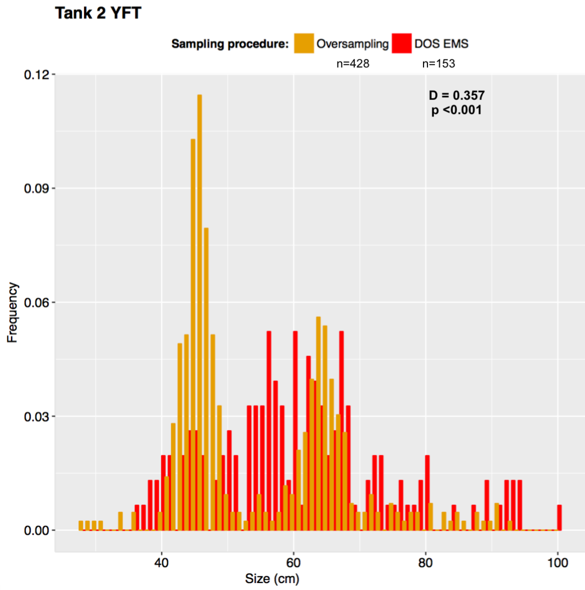
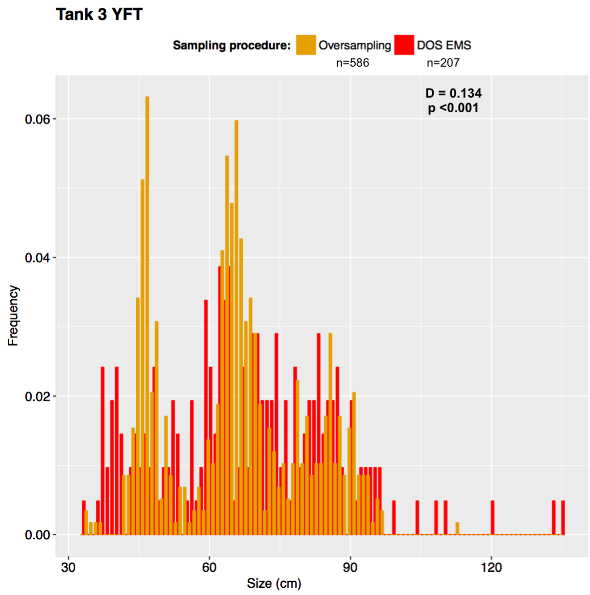
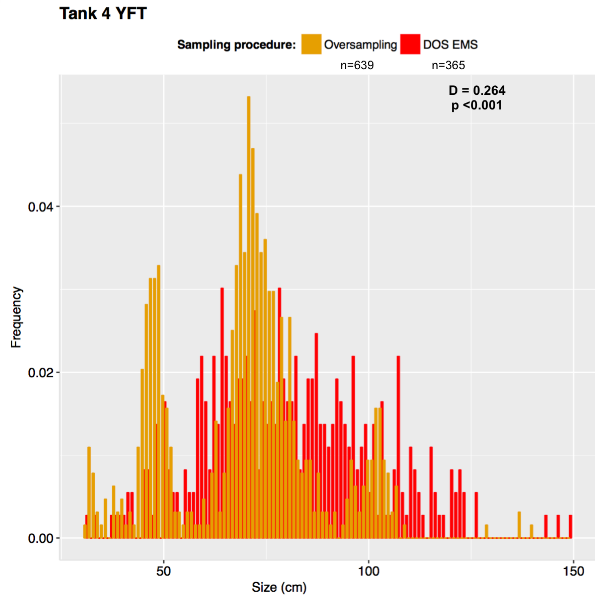


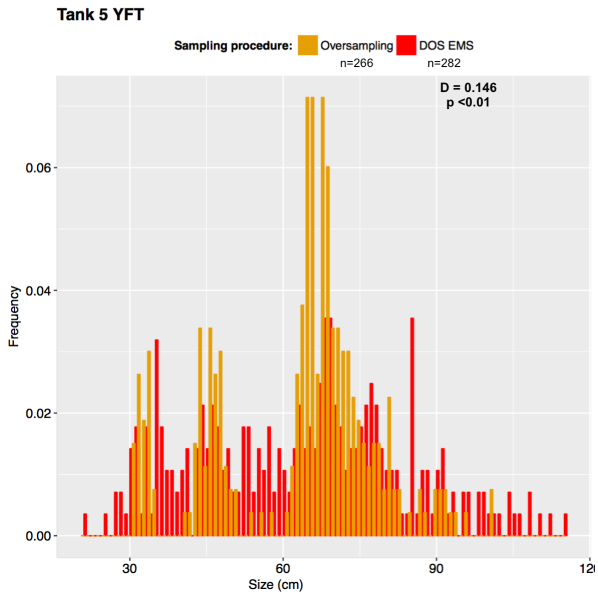
Figure 154: Size frequency histograms of skipjack tuna (SKJ) by tank for Oversampling and DOS EMS S2 procedures. n indicates the number of individuals measured by each procedure. D statistic and P-value of the Kolmogorov-Smirnov test are indicated.

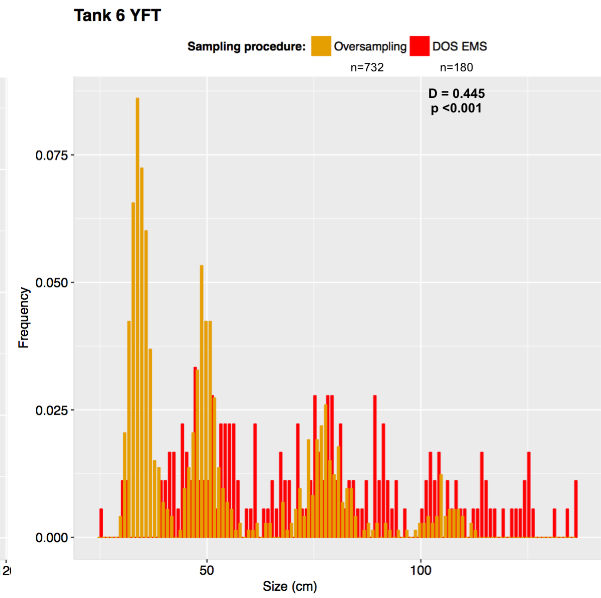

Tank 1 YFT
Sampling procedure: Oversampling DOS EMS
n=275 n=34
D = 0.284
p <0.05
Frequency
0.10
0.05
0.00
50
75
100
Size (cm)


Tank 2 YFT
Sampling procedure: Oversampling DOS EMS
n=428 n=153
D = 0.357
p <0.001
Frequency
0.12
0.09
0.06
0.03
0.00
40
60
80
100
Size (cm)


Tank 3 YFT
Sampling procedure: Oversampling DOS EMS
n=586 n=207
D = 0.134
p <0.001
Frequency
0.06
0.04
0.02
0.00
30
60
90
120
Size (cm)


Tank 4 YFT
Sampling procedure: Oversampling DOS EMS
n=639 n=365
D = 0.264
p <0.001
Frequency
0.04
0.02
0.00
50
100
150
Size (cm)


Tank 5 YFT
Sampling procedure: Oversampling DOS EMS
n=266 n=282
D = 0.146
p <0.01
Frequency
0.06
0.04
0.02
0.00
30
60
90
Size (cm)


Tank 6 YFT
Sampling procedure: Oversampling DOS EMS
n=732 n=180
D = 0.445
p <0.001
Frequency
0.075
0.050
0.025
0.000
50
100
Size (cm)

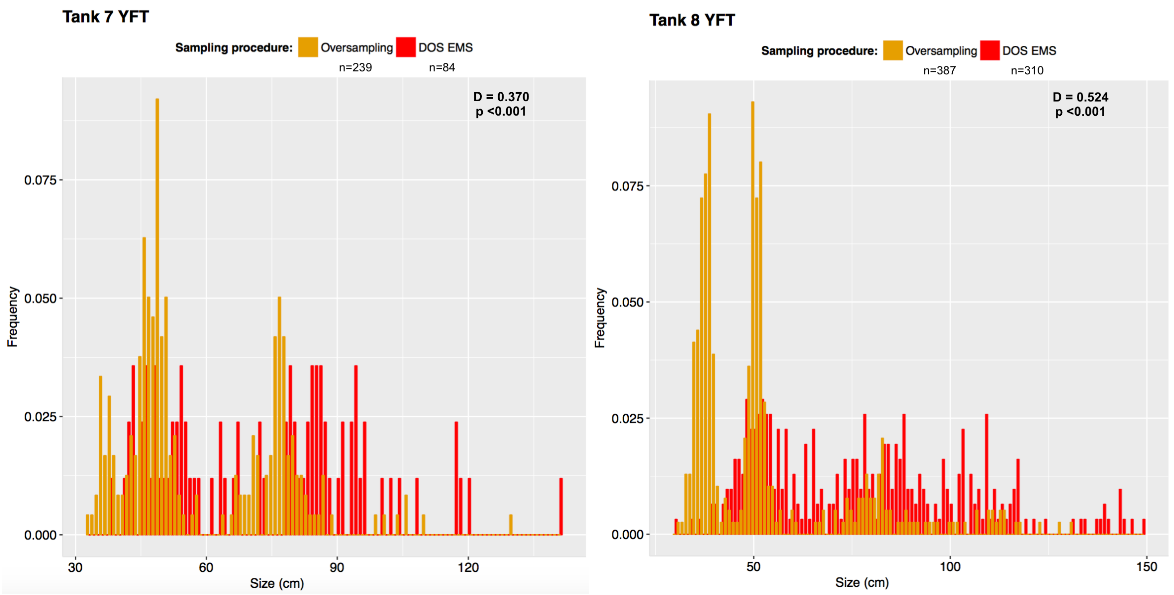
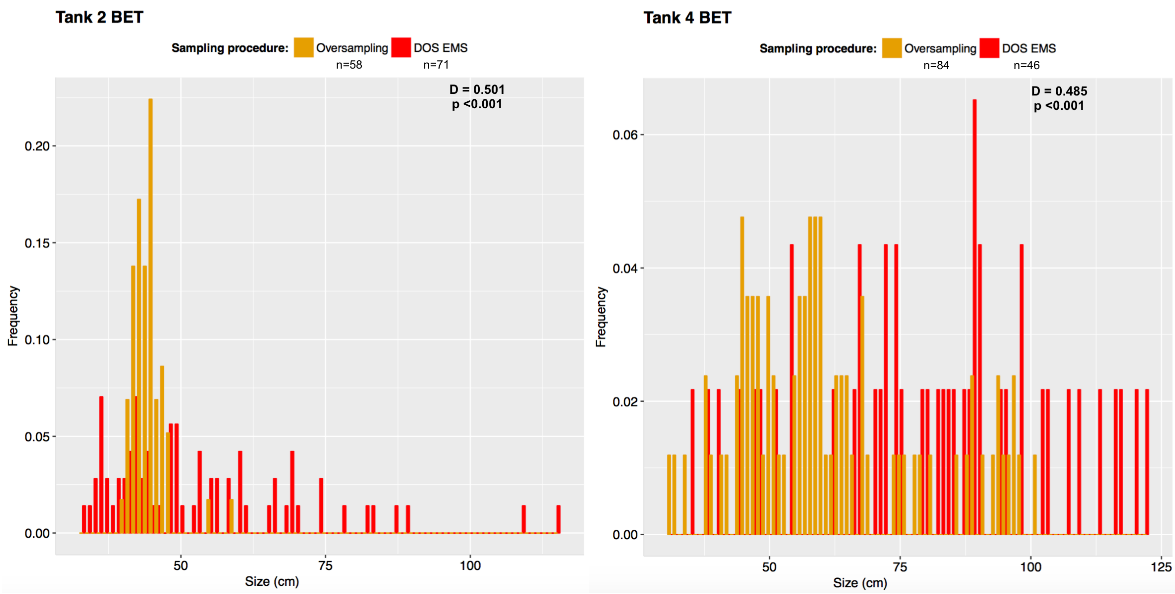


Figure 155: Size frequency histograms of yellowfin tuna (YFT) by tank for Oversampling and DOS EMS S2 procedures. n indicates the number of individuals measured by each procedure. D statistic and P-value of the Kolmogorov-Smirnov test are indicated.



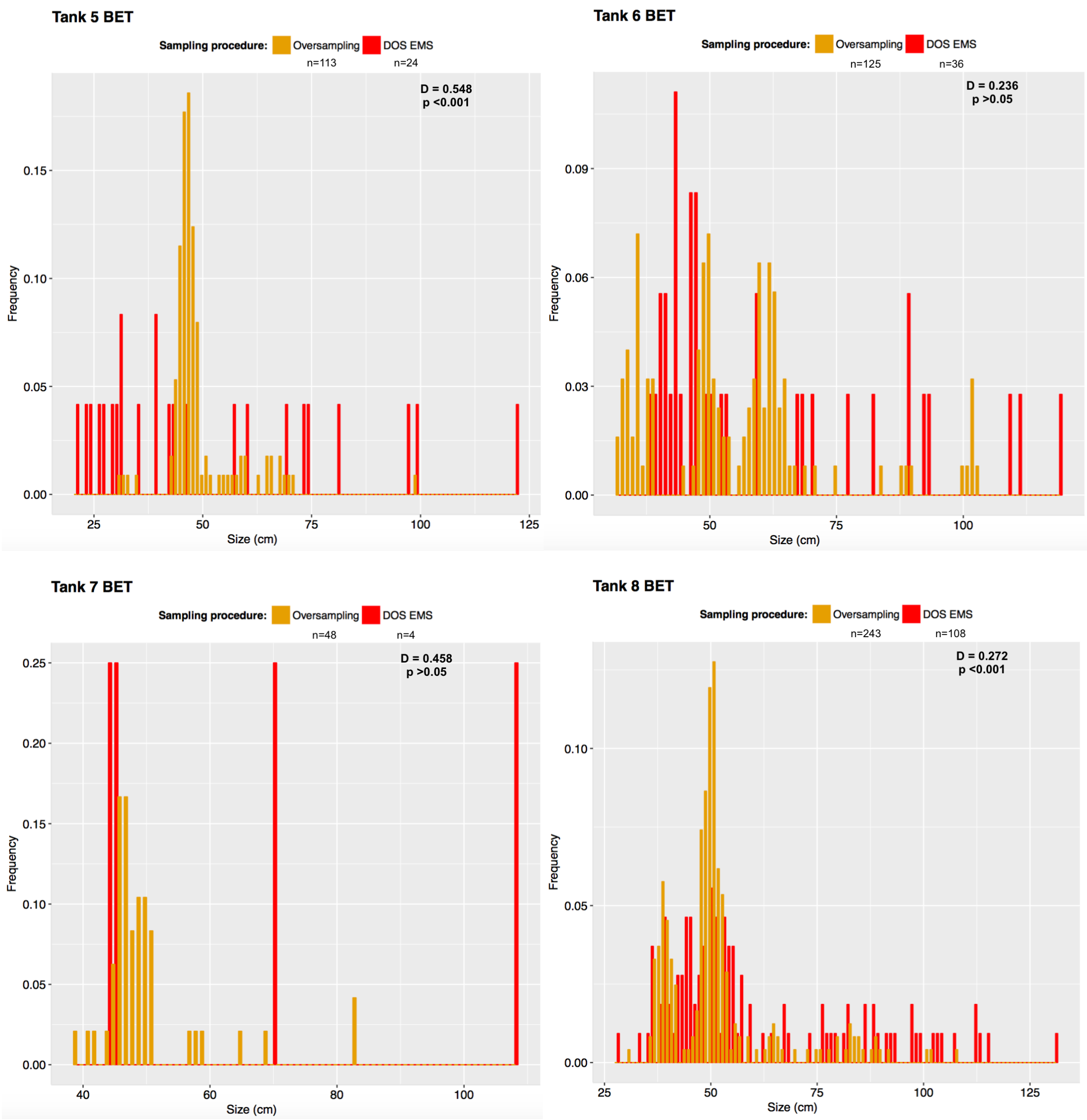


Figure 156: Size frequency histograms of bigeye tuna (BET) by tank for Oversampling and DOS EMS S2 procedures. n indicates the number of individuals measured by each procedure. D statistic and P-value of the Kolmogorov-Smirnov test are indicated.

Universitat d'Alacant
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GOBIERNO DE ESPAÑA

MINISTERIO DE AGRICULTURA, ALIMENTACIÓN Y MEDIO AMBIENTE

CIHEAM

El Máster Internacional en GESTIÓN PESQUERA SOSTENIBLE está organizado conjuntamente por la Universidad de Alicante (UA), el Ministerio de Agricultura, Alimentación y Medio Ambiente (MAGRAMA), a través de la Secretaría General de Pesca (SGP), y el Centro Internacional de Altos Estudios Agronómicos Mediterráneos (CIHEAM), a través del Instituto Agronómico Mediterráneo de Zaragoza (IAMZ).

El Máster se desarrolla a tiempo completo en dos años académicos. Tras completar el primer año (programa basado en clases lectivas, prácticas, trabajos tutorados, seminarios abiertos y visitas técnicas), durante la segunda parte los participantes dedican 10 meses a la iniciación a la investigación o a la actividad profesional realizando un trabajo de investigación original a través de la elaboración de la Tesis Master of Science. El presente manuscrito es el resultado de uno de estos trabajos y ha sido aprobado en lectura pública ante un jurado de calificación.

The International Master in SUSTAINABLE FISHERIES MANAGEMENT is jointly organized by the University of Alicante (UA), the Spanish Ministry of Agriculture, Food and Environment (MAGRAMA), through the General Secretariat of Fisheries (SGP), and the International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM), through the Mediterranean Agronomic Institute of Zaragoza (IAMZ),

The Master is developed over two academic years. Upon completion of the first year (a programme based on lectures, practicals, supervised work, seminars and technical visits), during the second part the participants devote a period of 10 months to initiation to research or to professional activities conducting an original research work through the elaboration of the Master Thesis. The present manuscript is the result of one of these works and has been defended before an examination board.